UNIVERSIDADE FEDERAL DO PARANÁ

JOÃO HENRIQUE PEROTTA

PERIOPERATIVE CHANGES IN ACID-BASE STATUS AND METABOLIC PROFILE OF COWS WITH LEFT ABOMASAL DISPLACEMENT TREATED BY ONE-STEP LAPAROSCOPIC OR OPEN SURGICAL ABOMASOPEXY

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Tese apresentada ao Programa de Pós-Graduação em Ciências Veterinárias, Área de Concentração em Clínica Cirúrgica Veterinária, Setor de Ciências Agrárias, Universidade Federal do Paraná, como requisito parcial à obtenção do título de Doutor em Ciências Veterinárias.

Orientador: Prof. Dr. Ivan Roque de Barros Filho

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PROGRAMA DE PÓS GRADUAÇÃO EM CIÊNCIAS VETERINÁRIAS

UFPR

Ata da Defesa de Tese do Candidato ao Título de Doutor em Ciências Veterinárias, JOÃO HENRIQUE PEROTTA, área Ciências Veterinárias, do PPGCV realizada em 07.10.2016.

Às oito horas e trinta minutos do dia sete do mês de outubro do ano dois mil e dezesseis, no Anfiteatro do Hospital Veterinário do Setor de Ciências Agrárias da UFPR, reuniu-se a Comissão Examinadora constituída pelos seguintes membros Professor Doutor Ivan Roque de Barros Filho; Professor Doutor Rüdiger Daniel Ollhoff; Professora Doutora Elizabeth Moreira dos Santos Schmidt; Professora Doutora Cristina Santos Sotomaior e o Professor Dr. Newton Pohl Ribas, com a finalidade de argüir o doutorandoa **JOÃO HENRIQUE PEROTTA** candidato ao Título de Doutor em Ciências Veterinárias, área Ciências Veterinárias, que ofereceu para análise da Comissão a Tese intitulada **"PERIOPERATIVE CHANGES IN ACID-BASE STATUS AND METABOLIC PROFILE OF COWS WITH LEFT ABOMASAL DISPLACEMENT TREATED BY ONE-STEP LAPAROSCOPIC OR OPEN SURGICAL ABOMASOPEXY"**. Abertos os trabalhos o candidato, cumprindo determinação regimental, fez uma breve exposição oral a respeito de sua Tese. Terminada a exposição, o Presidente Professor Doutor Ivan Roque de Barros Filho declarou aberta a argüição do candidato pelos membros da banca, finalizada pelo próprio Presidente. Concluída a argüição, a Comissão Examinadora reuniu-se para avaliar o Candidato. A Comissão Examinadora considerou que a Tese foi feita de maneira adequada

Quanto à apresentação do Candidato durante a Defesa, a Comissão Examinadora apresentou de maneira clara e objetiva

Reabertos os trabalhos, de acordo com o Art. 79 da Resolução nº 65/09–CEPE, o candidato foi considerado APTO para obtenção do título de Doutor em Ciências Veterinárias, Área Ciências Veterinárias, encerrando os trabalhos da Defesa de Tese dos quais, eu, ______________________, lavrei a presente Ata que vai por mim assinada ______________ e por todos os Membros da Comissão Examinadora. Curitiba, 7 de outubro de 2016.

Professor Doutor Ivan Roque de Barros Filho
Orientador/Presidente

Professora Dra. Elizabeth Moreira dos Santos Schmidt
Membro

Professora Doutora Cristina Santos Sotomaior
Membro

Professor Doutor Rüdiger Daniel Ollhoff
Membro

Professor Doutor Newton Pohl Ribas
Membro

DEDICATÓRIA

Aos animais, razão da minha profissão!

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EPÍGRAFE

“Phantasie ist wichtiger als Wissen, denn Wissen ist begrenzt”
Albert Einstein

RESUMO

O deslocamento de abomaso à esquerda é uma doença que afeta principalmente vacas leiteiras no período de transição. Possui como sinais clínicos queda na ingestão de alimentos e na produção leiteira e som ressonante timpânico à auscultação no abdome esquerdo. O tratamento é basicamente cirúrgico, sendo utilizadas técnicas cirúrgicas convencionais como a omentopexia pelo flanco esquerdo ou direito. Porém, estas técnicas são invasivas e o uso de antibióticos e anti-inflamatórios no pós-operatório é inevitável, aumentando os custos e obrigando o descarte do leite. A técnica de abomasopexia por laparoscopia foi desenvolvida para reduzir as complicações associadas com as técnicas cirúrgicas convencionais. A técnica laparoscópica em um passo possui a vantagem de ser mais rápida, evitando derrubar o animal. Assim, objetivou-se estudar o efeito da técnica de abomasopexia por laparoscopia em um passo sobre a produção leiteira, consumo de alimentos, equilíbrio ácido-base e eletrolítico e parâmetros metabólicos em vacas leiteiras acometidas naturalmente por deslocamento de abomaso à esquerda. Esta tese está dividida em quatro capítulos. O capítulo inicial apresenta uma introdução e revisão de literatura sobre o assunto, enfatizando a relevância e a finalidade da pesquisa. O segundo capítulo apresenta um artigo científico intitulado “Laparoscopia em um passo para a correção do deslocamento de abomaso à esquerda em vacas leiteiras de alta produção”, aceito para publicação na Revista Semina: Ciências Agrárias. O trabalho relatou as primeiras experiências do uso da técnica laparoscópica em um passo no Brasil, assim como as dificuldades encontradas durante a sua execução. O terceiro capítulo, intitulado “Complicações cirúrgicas associadas com a abomasopexia por laparoscopia em um passo em vacas leiteiras”, relata as complicações encontradas durante a execução da técnica laparoscópica, como também durante o período de observação pós-operatório. O quarto capítulo, “Abomasopexia por laparoscopia em um passo em comparação à abomasopexia via laparotomia pelo flanco direito no tratamento do deslocamento de abomaso à esquerda em vacas leiteiras” resume os principais achados desta pesquisa, enfatizando as alterações do equilíbrio ácido-base e dos parâmetros metabólicos. A conclusão obtida nesta pesquisa foi que a técnica de abomasopexia por laparoscopia em um passo retorna o fluxo abomasal e que não há diferença entre esta técnica e a abomasopexia pelo flanco direito, no que tange à recuperação do animal.

Palavras-chave: abomasopexia, laparoscopia, deslocamento de abomaso, vacas leiteiras, equilíbrio ácido-base.

ABSTRACT

A left displacement of the abomasum is a common disease among dairy cattle during their transition period. The cows present the following clinical signs: a drop in milk yield and feed intake, and a resonant/tympanic percussion note during auscultation of the left paralumbar fossa. The treatment of a displaced abomasum generally involves surgical approaches, such as omentopexy via the left or right paralumbar fossae. However, these techniques are invasive, and the follow-up administration of antibiotics and anti-inflammatories is required; this increases the cost of care and requires disposal of milk that is contaminated by antibiotics. The one-step laparoscopic abomasopexy technique was developed to reduce the complications associated with laparotomy approaches. This technique avoids positioning the cow in dorsal recumbence, and is faster than the two-step laparoscopic abomasopexy. The objective of this thesis was to investigate the effects of the one-step laparoscopic abomasopexy on the milk yield, feed intake, acid-base balance, and biochemical profile of dairy cows with a left displaced abomasum. This thesis is divided into four chapters. The introductory chapter reviews this topic, and emphasizes the relevance and the purpose of this research. The second chapter presents a study entitled, "One-step laparoscopy for the correction of left abomasal displacement in high-yielding Holstein dairy cows", published in the journal Semina: Ciência Rural. This report assesses the efficacy of the one-step laparoscopic abomasopexy, the first case of its use, in Brazil, and details the difficulties encountered during the surgical procedure. The third chapter, entitled, "Surgical complications associated with one-step laparoscopic abomasopexy in dairy cows", describes the complications observed during the surgical procedures and the post-operatory period in cows operated by the one-step laparoscopic abomasopexy. The fourth chapter, entitled, "One-step laparoscopic abomasopexy versus abomasopexy via the right paralumbar fossa to treat left abomasal displacement in dairy cows", summarizes the main research findings, and compiles the acid-base balance and metabolic profiles. This research concludes that one-step laparoscopic abomasopexy addresses the issue of recovery of abomasal flux, and that, furthermore, similar rates of clinical recovery among the cows operated by either laparoscopy or the paralumbar fossa laparotomy, were evident.

Keywords: abomasopexy, laparoscopy, left abomasal displacement, dairy cows, acid-base balance

LIST OF ABBREVIATIONS AND SYMBOLS

UFPR – Universidade Federal do Paraná
LAD – left abomasal displacement
RAD – right abomasal displacement
RAV – right abomasal volvulus
NEB – negative energy balance
mmol/L – millimole per liter
NEFA – non-esterified fatty acids
BHBA – beta-hydroxybutyrate
DA – displaced abomasum
mEq/L – milliequivalent per liter
AG- anion gap
SID – strong ion difference
BE – base excess
DAE – deslocamento de abomaso à esquerda
PCV – packed cell volume
Na^+ – sodium
K^+ – potassium
Cl^- – chloride
UC – unmeasured cations
UA – unmeasured anions
°C – degrees Celsius
mL – milliliters
mm - millimeters
cm – centimeters
L – liters
Bar – atmospheric air pressure unit
V – volts
IU – international units
min – minutes
vs – versus
PCO_2 – partial pressure of carbon dioxide
RV – reference values

SUMMARY

1. INTRODUÇÃO

O deslocamento de abomaso à esquerda (DAE) é definido como um enchimento progressivo de gás do corpo e fundo do abomaso, resultando em um deslocamento caudodorsal do órgão, situando-se entre o rúmen e a parede abdominal esquerda. A etiologia é multifatorial e envolve o aumento de ácidos graxos voláteis no rúmen e abomaso, hipocalcemia, balanço energético negativo, cetose, alcalose metabólica, prostaglandinas e lesão no nervo vago, além de fatores genéticos e mecânicos. Porém, nenhum desses fatores foi estabelecido como agente etiológico experimentalmente, e o mecanismo exato do DAE permanece desconhecido.

Esta doença tem distribuição mundial, principalmente em regiões de atividade leiteira intensiva, tendo uma incidência em vacas leiteiras entre 2 e 5%. Entretanto, ocorre raramente em animais destinados à produção de carne. Pode afetar tanto machos quanto fêmeas e animais de qualquer idade, porém tem maior incidência em fêmeas no período de transição, aumentando com a idade e com o número de partos. As perdas econômicas estimadas com o deslocamento de abomaso giram em torno de US$ 250 a US$ 450 por animal e são em decorrência da redução na produção de leite e dos custos do tratamento ou do descarte.

Os sinais clínicos associados com o DAE são diminuição na produção leiteira e na ingestão de alimentos, fezes escassas e escurecidas, som ressonante timpânico durante a auscultação e percussão do abdômen. A obstrução da passagem da ingesta para o abomaso resulta em um refluxo de conteúdo abomasal para o rúmen, elevando a concentração de íons cloreto e reduzindo o pH ruminal. Uma consequência sistêmica do refluxo abomasal é a alcalose metabólica hipoclorêmica e hipocalêmica que se desenvolve em um número significativo de vacas.

O tratamento é basicamente cirúrgico e inclui diversas técnicas, todas com vantagens e desvantagens. As técnicas com acesso por laparotomia incluem abomasopexia por acesso paramediano, omentopexia ou abomasopexia por laparotomia pelo flanco esquerdo e omentopexia por laparotomia pelo flanco direito. As técnicas minimamente invasivas incluem a sutura às cegas e a sutura toggle.

Em 1998, Janowitz introduziu a técnica laparoscópica minimamente invasiva para tratamento do DAE. Este método combina as vantagens do método tradicional aberto, como segurança e altas taxas de sucesso, com a praticidade da abomasopexia percutânea.

A técnica de abomasopexia por laparoscopia pelo flanco esquerdo em um passo foi desenvolvida por Christiansen e Barisani em 2004, sendo uma modificação da técnica de Janowitz. O procedimento cirúrgico é semelhante, exceto que a sutura é conduzida ventralmente, cranial à cicatriz umbilical por uma haste especial chamada de "spieker".

A técnica de abomasopexia por laparoscopia apresenta uma recuperação mais rápida dos animais, principalmente com relação à produção leiteira. Além disso, por ser uma técnica minimamente invasiva, minimiza o uso de antibióticos e anti-inflamatórios no pós-operatório, reduzindo as perdas econômicas com descarte de leite contaminado e gastos com medicamentos. Outra vantagem está relacionada com o bem-estar animal, por ser uma técnica menos traumática quando comparada às técnicas por laparotomia pelo flanco, minimizando o desconforto gerado pela operação. A abomasopexia por laparoscopia em um passo dispensa a necessidade de derrubar e manter o animal em decúbito dorsal, facilitando o manejo e contenção e reduzindo o estresse do animal, além de ser um procedimento mais rápido, quando comparado à técnica de laparoscopia em dois passos.

O objetivo desse trabalho foi avaliar a eficácia da abomasopexia em um passo no tratamento de vacas leiteiras de alta produção a campo no Brasil. Foram avaliadas as alterações metabólicas e do equilíbrio ácido-base antes e até 72h após o tratamento, os quais foram comparados com os resultados obtidos de vacas tratadas pela abomasopexia ventral por laparotomia pela fossa paralombar direita.

O primeiro capítulo dessa tese é uma revisão de literatura sobre o deslocamento de abomaso, os fatores predisponentes relacionados com essa doença, as principais alterações clínicas encontradas em vacas com o abomaso deslocado, assim como os principais tratamentos disponíveis. O segundo capítulo é o artigo intitulado "One-step laparoscopy for the correction of left abomasal displacement in high-yielding Holstein dairy cows", submetido e aprovado para publicação na revista Semina: Ciências Agrárias. Este artigo objetivou relatar a primeira experiência do uso da técnica laparoscópica no Brasil.

O terceiro capítulo é o artigo intitulado "Surgical complications associated with one-step laparoscopic abomasopexy in dairy cows", submetido para publicação à revista The Open Veterinary Journal. Este artigo objetivou relatar as complicações e dificuldades encontradas durante a execução da técnica de abomasopexia por laparoscopia, e que são pouco abordadas pela literatura.

O quarto capítulo desta tese é o artigo “One-step laparoscopic abomasopexy versus abomasopexy via right paralumbar fossa to treat left abomasal displacement in dairy cows”, submetido para a revista Pesquisa Veterinária Brasileira. Neste artigo são abordadas as alterações do equilíbrio ácido-base e metabólicas em vacas com deslocamento de abomaso e tratadas por abomasopexia por laparoscopia ou por laparotomia.

2. CHAPTER 1 - LITERATURE REVIEW

Abomasal displacement is defined as a non-anatomical position of the abomasum within the abdominal cavity. The disease is classified in three types according to the position of the abomasum: left abomasal displacement (LAD), right abomasal displacement (RAD) and right abomasal volvulus (RAV) (Niehaus 2008).

The left displacement of the abomasum, which is the most common position for a displaced abomasum, accounts for up to 90% of the reported cases within the literature (Shaver 1997). It is described as a progressive dilation of the body and fundus of the abomasum caused by gas; this displaces the viscus dorsocaudally, between the rumen and the left body wall (Dirksen 2006).

The pathogenesis of abomasal displacement remains to be fully established and several factors are associated with the disease (Geishauser 1995). The disease may be influenced by an increased ruminal and abomasal production of volatile fatty acids (Svendsen and Kristensen 1970), negative energy balance (Shaver 1997), hypocalcemia (Curtis *et al*., 1983), ketosis (Rohrbach *et al*., 1999), metabolic alkalosis (Poulsen and Jones 1974), and the dysregulated production of prostaglandins and endotoxins (Vlaminck *et al.*, 1985). Nonetheless, the etiologic agents have yet to be experimentally established (Geishauser 1995).

The accumulation of gas into the abomasum is a decisive factor affecting abomasal displacement (van Winden and Kuiper 2003). The gas is predominantly methane and carbonic gas, which is produced in the abomasum or the forestomaches from the metabolism of short chain fatty acids from the feed (van Winden and Kuiper 2003; Doll, Sickinger and Seeger 2009). However, the gas is accumulated in the abomasum only in the presence of abomasal hypomotility or atony (Shaver 1997; Niehaus 2008; Doll, Sickinger and Seeger 2009). The change in abomasal contraction pattern is induced by the following factors: influx of water and electrolytes inside of the abomasum, endotoxemia due to a retained placenta, the incidence of enteritis, peritonitis and mastitis (Doll, Sickinger and Seeger 2009), ketosis (van Winden and Kuiper 2003), and hypocalcemia (Massey *et al*., 1993; Shaver, 1997).

High-yielding dairy cows between 4-7 years of age are affected more frequently. Additionally, the risk of a displaced abomasum increases with age (Constable *et al*., 1992). Almost 90% of the cases are diagnosed during the transition period (from 2 weeks pre-partum to 4 weeks post-partum) (Shaver 1997; Dirksen, 2006). This period is characterized by endocrine and metabolic disturbances and sudden dietary changes (Mulligan and Doherty 2008): decrease in feed intake and ruminal fill, increased concentrate and decreased roughage in the diet, reduced exercise, and the incidence of hypocalcemia, hypomagnesemia, hypokalemia and ketosis (van Winden *et al.*, 2003; van Winden and Kuiper 2003; Shaver 1997; Trent 2005; Dirksen 2006; Niehaus 2008).

Additionally, fatty mobilization leads to immune system dysfunction, increasing the susceptibility of infectious and metabolic diseases during transition period (Sordillo and Raphael 2013). According to Mulligan and Doherty (2008), the etiology of reproductive (retained placenta and metritis) and metabolic diseases (ketosis and fatty liver), hypocalcemia and displacement of abomasum is inter-related.

2.1. ABOMASAL DISPLACEMENT IN BRAZIL

In 1963, Silvio Camerino Paes Barreto, from Universidade Rural de Pernambuco, and Gerrit Dirksen, from University of Veterinary Medicine Hannover - Germany, published the first manuscript about displacement of abomasum in Brazil. The article, entitled “Sôbre a deslocação do abomaso para o lado esquerdo, em bovino”, provides information about anatomy, etiology, clinical signs, diagnosis and treatment. In 1977, Jardim and coworkers from Goiás published a case of abomasal volvulus. In 1990, during the XVI World Buiatrics Congress in Salvador, Birgel and coworkers published 12 cases of displaced abomasum in São Paulo State. The large Animal Hospital at Faculdade de Medicina Veterinária e Zootecnia – UNESP Campus de Botucatu diagnosed and treated 20 cows with displaced abomasum from 1989 to 2015 (Santarosa *et al.*, 2015).

Although there is a lack of prevalence study in Brazil (Cardoso 2007), the displacement of abomasum is common in high yield farms from different Brazilian States, as Rio Grande do Sul (Cardoso 2007), Pernambuco (Câmara *et al.*, 2007; Câmara *et al*., 2010), São Paulo (Birgel *et al*., 1990) and Paraná (Reichert Netto 1992; Tabeleão *et al.*, 2005; Dÿck 2016). Recently, the incidence rate for abomasal displacement in Parana State was 2.08% (Dÿck 2016).

2.2. NUTRITION AND METABOLISM

Three metabolic disorders are associated with LAD: negative energy balance (NEB), hypocalcemia, and metabolic alkalosis (van Winden and Kuiper 2003).

Nutritional intake influences the incidence of a displaced abomasum; this was implicated as the major cause of LAD (Dirksen 1961; Cameron *et al*., 1998). Reduced roughage fed near calving is associated with a displaced abomasum (Cameron *et al*., 1998). This is because a reduced feed intake decreases the ruminal filling and enables the abomasum to displace to the left (Dirksen 1961). The ruminal fill is also implicated as a cause for hypomotility of the abomasum (van Winden and Kuiper 2003).

Blood calcium concentration decreases considerably towards calving, and reaches even lower levels at 12-24 h after birth (Goff 2008). Approximately 50% of dairy cows showed subclinical hypocalcemia, which is characterized by decreased blood calcium concentrations, without the clinical sign of milk fever (Oetzel 2013). Hypocalcemia affects cows negatively because blood calcium is essential for muscle function and gastrointestinal motility (Oetzel 2013). Hypocalcemia increases the risk of LAD by 4.8-fold, since abomasal motility is inhibited when blood calcium levels are <1.2 mmol/L (Massey *et al*., 1993). Hypocalcemia is also induced by the state of metabolic alkalosis because of the reduced receptor sensitivity for the parathyroid hormone (van Winden and Kuiper 2003).

Cows with an elevated body score during parturition, or those that are characterized by an NEB, are at an increased risk of LAD. This disease is associated with ketosis and a fatty liver (Shaver 1997). Postpartum dairy cows develop NEB; however, not every cow is adversely affected. The incidence of this disease is dependent on the severity and the duration of NEB (van Winden and Kuiper 2003). Negative energy balance is characterized by increased plasma concentration of non-esterified fatty acids (NEFA) (Leblanc, Leslie and Duffield 2005; Duffield *et al*., 2009); prepartum cows with an increased plasma NEFA concentration showed an increased risk of LAD (Cameron *et al*., 1998).

Ketosis can be classified as either clinical or subclinical. Clinical ketosis is characterized by an accumulation of ketone bodies (mostly BHBA) in the blood, urine, or milk, and is associated with several clinical signs, including inappetence, weight loss, and dehydrated feces. Subclinical ketosis is also described as an accumulation of ketone bodies in either the blood, urine, or milk, but lacks these apparent clinical signs. Approximately 40% of dairy cows are affected (Gordon, Leblanc and Duffield 2013).

Close to 50% of cows with LAD showed ketosis prior to the incidence of abomasal displacement (van Winden *et al*., 2003; Duffield *et al*., 2009). Researches has shown that cows with LAD showed increased levels of BHBA, in comparison to unaffected cows (Van Winden *et al*., 2003; Leblanc, Leslie and Duffield 2005; Cardoso 2007).

Ketosis decreases the feed intake and consequently, the ruminal filling. It induces hypomotility in the rumen and abomasum, and increases the accumulation of gas in the abomasum and forestomaches. These factors predispose the occurrence of LAD (van Winden *et al*., 2003; Duffield *et al*., 2009).

The association of increased insulin concentration, induced by hepatic lipidosis and insulin resistance, is common to cows with LAD. This predisposes the cow to LAD as increased levels of insulin decreased the abomasal motility (van Meirhaeghe *et al*., 1988a,b).

2.3. STRESS-RELATED, MUSCULOSKELETAL, REPRODUCTIVE, INFLAMMATORY AND INFECTIOUS DISORDERS

Diseases affecting the reproductive tract are related to the incidence of LAD. The risk of abomasal displacement is increased in cases involving metritis, retained placenta, and twins, by a factor of 4.26, 6.62, and 3.25 folds, respectively (Markusfeld 1986).

Endotoxemia arises from bacterial infections such as peritonitis, mastitis, and endometritis, or from gastrointestinal translocation. Bacterial endotoxin can inhibit abomasal motility, either directly or indirectly, inducing hypocalcemia (Doll, Sickinger, and Seeger 2009). However, Wittek, Fürll, and Constable (2004) found a lower prevalence of endotoxemia in cows with LAD than in healthy cows.

Almost 20% of dairy cows have signs of subacute ruminal acidosis (SARA). This disease was incriminated in the etiology of LAD, associated with decreased feed intake, probably due systemic inflammatory changes (Plaizier *et al*., 2009; Mulligan and Doherty 2013).

Additionally, reproductive and infectious diseases were shown to induce stress in dairy cows and, the stress was linked to the risk factor of LAD (Leblanc et al., 2005; Doll, Sickinger and Seeger 2009).

Chronic or excessive inflammation is related with increased diseases in the transition period. Chronic inflammation is present in fat cows. These overconditioned cows have greater incidence of diseases in transition period, influenced by increased NEFA, which induce chronic inflammation (Kim and Suh 2003; de Heredia *et al.,* 2012). Intense lipid mobilization is associated with immune impairment (Mulligan and Doherty 2013).

Lameness was shown to be comorbid with LAD (Freick *et al*., 2013), and more prevalent among affected herds (Lotthammer 1992). Lame cows showed a reduced feed intake and consequently, a reduced ruminal filling; this resulted in a displaced abomasum (van Winden 2002).

2.4. GENETICS

The disease is common in various breeds as Jersey, Holstein, Guernsey, Ayrshire, Simmental and Brown Swiss, however the risk is highest in Holstein and Guernsey (Constable *et al*., 1992; Zerbin *et al*., 2015).

High dairy yielding cows have greater chances of developing LAD; the process of genetic selection for milk yielding also selects for cows that have a framed body, and a high ruminal fill and abomasal volume (van Winden and Kuiper 2003; Dirksen 2006). The heritability of LAD ranged between 0.11 and 0.41; this value considers genetic predisposition as a risk factor for the occurrence of displacement (Constable *et al*., 1992; Doll, Sickinger and Seeger 2009). Mömke et al. (2013) identified 36 nucleotides and 17 chromosomes associated with LAD.

2.5. CLINICAL SIGNS AND DIAGNOSIS

LAD is clinically characterized by a decrease in milk yield and feed intake, scant and dark feces, ruminal hypomotility and a resonant, tympanic percussion note during auscultation and percussion/succussion of the left paralumbar fossa. Additionally, dehydration is evident, which is indicated by the incidence of mild enophthalmia, decreased skin turgor, and an increased heart rate (Trent 2005). The abomasum can be palpated rectally in extreme cases of dilation. The rumen is displaced medially in some cows (Dirksen 2006).

A measure of the acid-base balance shows a pH of less than 7.0 in the analysis of the ruminal juice. Additionally, an increase in chloride ion concentration (above 30 mmol/L) was evident. An acidic smell from the ruminal juice has been reported in some cases. These alterations result from the reflux of abomasal content into the rumen. The differential diagnosis for LAD considers the clinical presentation of ruminal bloat, peritonitis, pneumoperitoneum, ascites, and cecal dilation/torsion (Dirksen 2006).

2.5.1. Acid-Base and Electrolyte Abnormalities in LAD

Changes in electrolyte balance in cows with LAD are characterized by hypochloremic and hypokalemic metabolic alkalosis, increased bicarbonate ion concentration and an excess of base (Barros Filho 2002; Dirksen 2006).

Under physiological conditions, chloride is reabsorbed in the small intestine, and is replaced by the secretion of bicarbonate ions in the intestinal lumen. When the transit of intestinal contents is reduced due to the incidence of LAD, the reflux of chloride ions and its sequestration to the forestomaches occurs; the bicarbonate ions remain in the blood. Consequently, the cow develops a metabolic hypochloremic alkalosis, as well as an increase in arterial pressure of carbonic gas and blood pH (Dirksen 2006; de Morais and Biondo, 2012; DiBartola and de Morais 2012).

The resulting hypochloremia and hypovolemia increases aldosterone secretion, which stimulates sodium reabsorption in the distal tubular kidney cells. The reabsorption of sodium ions involves an electroneutral mechanism that exchanges cations or co-transports it with a soluble anion. Initially, sodium ions are reabsorbed with chloride ions. Further reabsorption of sodium ions must be coupled with the exchange of either a potassium ion or a hydrogen ion. Hydrogen ions, which titrate the excess of bicarbonate ions, are initially reabsorbed with sodium ions. However, the severe hypokalemic state reverses the diffusion of hydrogen ions from the extracellular plasma to the intracellular fluid, in exchange for the facilitated diffusion of potassium ions. This exchange increases the secretion of hydrogen ions, by the kidneys, and results in paradoxical aciduria (Gingerich and Murdick 1975a; DiBartola 2012).

The percentage of cows with LAD and metabolic alkalosis, hypochloremia and/or hypokalemia varies considerably. Robertson (1966) found that hypochloremia and hypokalemia occurred in 48% and 41% of cows with LAD, respectively. Gingerich and Murdick (1975b) found that metabolic alkalosis, hypochloremia, and hypokalemia occurred, respectively, in 54%, 51%, and 74% of cows with LAD. Barros Filho (2002) reported that metabolic alkalosis, hypokalemia, and hypochloremia occurred in 62%, 50%, and 14% of cows with LAD, respectively. Recently, Constable et al. (2013) reported hypokalemia in 55% of cows with LAD.

The strong ion difference (SID) is an independent influence on the animal's acid-base balance. This variable acts as an external influence on the regulatory system of pH, and is unaffected by other independent variables, such as PCO_2 and the total plasma concentration of non-volatile weak buffers. Nonetheless, the independent variables directly influence the dependent variables (Stewart 1978; Constable 1999). Strong ions are dissociated at physiologic pH and exert only an electrical effect, as opposed to a buffer effect, on the system. However, as the sum of cations is not equal to the sum of anions in the extracellular space, the system becomes characterized by an SID (Stewart 1978). The changes in SID that alter pH, and the concentration of bicarbonate ions, is usually a consequence of increased concentrations of sodium, chloride, phosphate or organic acids, or decreased concentrations of sodium or chloride (de Morais and Constable 2012).

Metabolic alkalosis is characterized by an increased SID due to a decreased chloride ion concentration or an increased sodium ion concentration. Conversely, metabolic acidosis is characterized by a decreased SID due to a decreased sodium ion concentration or an increase in either the chloride ion, phosphate ion, or the organic acid concentration (Constable 1997; de Morais and Constable 2012). The concentration of plasma protein also has an influence on the SID. For example, hypoproteinemia induces metabolic alkalosis and increases the SID, while hyperproteinemia induces metabolic acidosis and decreases the SID (Fencl and Rossing 1989). In scenarios involving normal concentrations of serum protein and phosphate, the difference in SID is associated with the changes in the concentration of the bicarbonate ion or base excess (Fencl and Rossing 1989; de Morais and Constable 2012).

The calculation of SID involves the measurement of total concentration of strong ions within the plasma; however, this is an arduous task due to the presence of non-identified strong ions. The clinical practice estimate was developed to assist the calculation of SID. This method employs the plasma concentrations of at least four strong ions, including sodium, potassium, chloride, and lactate. This is expressed by the following formula:

$$SID = ([Na^+] + [K^+]) – ([Cl^-] + [Lactate^-])$$ (Constable 1997) [01].

Furthermore, Constable (1999) showed that SID in ruminants could be also obtained by using only three strong ions, as indicated by the following formula:

$$SID = ([Na^+] + [K^+]) – [Cl^-]$$ [02]

Constable *et al*. (2005) showed that the formulae produced similar outcomes in the calculation of SID in diseased calves. The shortened version [02] of the original formula [01] (Constable 1997) provides only an estimate of SID and therefore, should only be referred to as the “measured SID” (Constable 1999). Additionally, this expression must be used because different measurement techniques that are employed for the derivation of sodium, chloride, potassium, and lactate concentrations result in significant interlaboratory variations in the measured SID. The two aforementioned approaches assume that the sum of the unmeasured strong cations is equivalent to the sum of the unmeasured strong anions; therefore, the concentration of the unmeasured strong ions can be significant in specific diseases, such as the incidence of ketosis in ruminants. Furthermore, specific measurements can be subject to error, and this contributes towards a larger cumulative error in the measured SID (Constable 2000).

The reference range of measured SID is 38-46 mEq/L (Constable 1999). The measured SID of venous blood is approximately 2 mEq/L greater than that of arterial blood. This is accounted for by the occurrence of a chloride shift within the pulmonary capillary bed (Zweens *et al.* 1977).

The elevated SID associated with hypochloremic metabolic alkalosis is observed in cows with LAD. Nonetheless, literature on the calculation of SID in cows with LAD is lacking. Furthermore, SID was shown to have increased in cows with LAD, to approximately 50 mEq/L (Barros Filho 2002).

The anion gap (AG) is the difference between the normally measured cations and anions. In theory, however, AG refers to the difference in concentration between unmeasured anions and cations (Shull 1978; Constable 1999). The following formula expresses AG:

$$AG = ([Na^+] + [K^+]) – ([Cl^-] + [HCO_3^-])$$

Electroneutrality suggests that all positive charges must be neutralized by an equal amount of negative charges (Emmett and Narins 1977). An excess of cations, compared to anions, has routinely been measured in blood samples; therefore, measurements have more often excluded the surplus of unmeasured anion (UA) compared to the concentration of unmeasured cations (UC) (Shull 1978; Feldman and Rosenberg 1981). Therefore, AG refers to the presence of anions—other than that of chloride and bicarbonate ions—that are required to neutralize the combined, positive charge conferred by the excess of sodium and potassium (Emmett and Narins 1977). Feldman and Rosenberg (1981) described that AG normally ranged from 12 to 16 mEq/L. However, Shull (1978) estimated that this value ranged from 13.9 to 20.2 mEq/L; in which the elevated AG required further neutralization by the presence of proteins, sulfates, phosphates, and others anions (Emmett and Narins 1977).

The elevation of AG reflects an elevated UA concentration or a decreased UC concentration (Constable 1999). An increased AG could be due to one of the following conditions (Feldman and Rosenberg 1981):

- Hypokalemia, hypocalcemia, or hypomagnesemia;
- Increased lactate, ketoacids, phosphate, and sulfates;
- Dehydration (hyperalbuminemia);
- Uremia.

A decreased AG reflects an increased UC concentration or a dysregulated retention of cations. A decreased AG could be due to one of the following conditions (Feldman and Rosenberg 1981):

- Hyperkalemia, hypercalcemia, or hypermagnesemia;
- Hypoalbuminemia;
- Dilution.

Anion Gap can be a useful, prognostic factor for the various causes of metabolic acidosis, which can be associated with either a normal or an elevated AG (Emmett and Narins 1977; Shull 1978; Feldman and Rosenberg 1981). In this scenario, an elevated AG is associated with metabolic acidosis because of the accumulation of organic and inorganic acids within the body. Furthermore, an increased AG has been associated with cases of dehydration, and has been observed in therapies involving highly concentrated sodium fluid, or those involving the use of certain antibiotics, such as penicillin. In ketosis, which is common among cows with LAD, the increased AG is associated with the retention of ketone acids. However, acetone is not considered as an acid, and does not affect AG (Emmett and Narins 1977; Shull 1978).

The causes of metabolic acidosis and a normal value of AG (Emmett and Narins 1977) are affected by the following conditions:

- Gastrointestinal bicarbonate loss – diarrhea;
- Rapid intravenous (IV) hydration;
- Post-hypocapnia.

Metabolic acidosis with a normal value of AG, which is occasionally termed, hyperchloremic acidosis, occurs because of the compensatory retention of chloride ions attributable to the loss of bicarbonate ions. Additionally, rapid rehydration with saline solution, or Ringer´s solution, dilutes the plasma bicarbonate and temporarily increases the chloride ion concentration (Shull 1978).

Cows with LAD generally show a normal or mildly elevated AG. The incidence of hypochloremia can be partially counterbalanced by an increase in the bicarbonate ion concentration; however, UA is necessary for the conservation of a normal gap (Shull 1978; Delgado-Lecaroz *et al*., 2000). Cows affected by an abomasal volvulus are showed and an elevated AG (>27.5 mEq/L) and have high mortality rates (Garry *et al*., 1988).

2.6. TREATMENT

The treatment of LAD is classified accordingly into three categories: clinical management, minimally invasive approaches, and laparotomies (Trent 2005; Seeger *et al.*, 2006).

Clinical management aims to reestablish abomasal motility by draining the accumulated gas and therefore returning the viscus to the anatomical position. This treatment is based on the administration of parasympathetic drugs and calcium, and rolling a left recumbent cow in 180° (Trent 2005). However, according to Dirksen (2006), the relapse rate can reach 70%.

Surgeries to correct both right and left abomasal displacement are commonly performed in dairy cows (Barlett *et al*., 1995) and are reliable approaches with low relapse rates (Barros Filho 2008). Several techniques have been developed to treat this disease since the first reports of abomasal displacement (AD) described by Begg (1950) and Ford (1950). Treatment choice is based on the cost-effectiveness of the procedure, the economic value of the cow, and the veterinarian's experience (Grymer and Sterner 1982).

Laparotomy via the left paralumbar fossa, or laparotomy associated with rumenotomy (Begg and Whiteford 1956), only returns the viscus to the anatomical position, and does not address the displaced abomasum (Jones 1952; Moore *et al*., 1954; Barrett and Nicol 1958). The use of abomasal fixation has been previously described within the literature; the treatment outcomes were reported by Straiton and McIntee (1959), via the right paramedian laparotomy, Ames (1968), via the left paralumbar fossa laparotomy, and Baker (1976), via the right paralumbar fossa laparotomy and ventral paramedian abomasopexy.

The procedures of right paralumbar fossa (Dirksen 1961, 1967) and left paralumbar fossa (Lagerweij and Numans 1962, 1968) omentopexy are highly accepted surgical methods because of their low rates of relapse (Bückner 1995).

Minimally invasive methods appeared as a cost-effective alternative, as opposed to surgical techniques (Hull 1972; Grymer and Sterner 1982). This method was used in mostly debilitated or less valuable cows (Barlett *et al*., 1995).

Lastly, minimally invasive techniques using laparoscopy were described in the treatment of both left (Janowitz 1998; Christiansen 2004; Barisani 2004; Babkine *et al*., 2006; Freick *et al*., 2013) and right abomasal displacement (Freick *et al*., 2013).

2.6.1. One-step laparoscopic abomasopexy

The one-step laparoscopic abomasopexy approach was described by Barisani (2004) in Italy and Christiansen (2004) in Germany.

According to Barisani (2004), the procedure involves the restraint of the cows in yokes and the skin is clipped 15 cm ventral to the transverse process and 5 cm caudal to the 13th rib. The skin, subcutaneous and muscles are then anesthetized using 10 mL of 2% lidocaine. Following the incision of the skin, a trocar (external diameter, 9 mm; internal diameter, 8 mm; and length, 11.5 cm) is introduced dorsocaudally, perforating the abdominal muscles and the peritoneal membrane. The laparoscope, 0º, 40 cm in length, and 7 mm in diameter, is introduced through this port and an air pump (at a rate of 4 L/min, 0.2 bar, and 230 V) is connected. The work port (12-mm in diameter and 12-cm in length) is introduced under laparoscopic guidance over the 11th intercostal space after clipping and local anesthesia with 2% lidocaine. The abomasum is localized, and the dorsal region (adjacent to the attachment of the greater omentum in the greater abomasal curvature) is perforated using a cannula. The toggle bar suture is introduced into the abomasum by using a rod (3 mm in diameter and 36.5 cm in length), and the viscera is then deflated. The thread is tied to the spieker tool (1 m in length and 11 mm in diameter), which is inserted between the rumen and the left body wall up to the right, ventral paramedian region. The toggle bar suture is exteriorized after a knock in the high extremity of the spieker localized in the left body wall, and is subsequently tied in the ventral abdomen using a gauze roll.

Christiansen (2004) modified the one-step laparoscopic abomasopexy technique. The procedure was performed conventionally until the introduction of the toggle bar suture into the abomasum. At this point, the spieker is introduced into the abdomen without the toggle suture. The ventral abdomen is perforated, and a nylon thread is tied to the ventral extremity of the spieker, which is then removed out of the abdomen. At this point, one end of the nylon thread is in the ventral, paramedian region and the other is positioned in the left body wall. The toggle suture is tied to the nylon thread, and the ventral extremity is pulled, exteriorizing the toggle bar suture, which is then tied.

The approaches of Christiansen (2004) and Barisani (2004) have been extensively used to treat LAD (Gnemmi 2006; Van Leeuwen *et al*., 2009, Freick *et al*., 2013); however, to the author´s knowledge, no randomized controlled trial has been conducted comparing one-step laparoscopic abomasopexy and abomasopexy or omentopexy via the right paralumbar fossa. Additionally, this method has never been used in Brazil to treat LAD.

3. GENERAL PURPOSE

To evaluate the efficacy of one-step laparoscopic abomasopexy in the treatment of LAD in dairy cows, and to compare with the procedure of abomasopexy via the right paralumbar fossa.

3.1. SPECIFIC PURPOSES

- To evaluate and compare the effects of the surgical procedures (one-step laparoscopic abomasopexy vs. abomasopexy via the right paralumbar fossa) on feed intake and dairy yield.
- To evaluate and compare the effects of the surgical procedures (one-step laparoscopic abomasopexy vs. abomasopexy via the right paralumbar fossa) on the acid-base and electrolyte profiles, and the fractional excretion of chloride, potassium, and sodium ions.
- To evaluate and compare the effects of the surgical procedures (one-step laparoscopic abomasopexy vs. abomasopexy via the right paralumbar fossa) on the blood concentration of β-hydroxybutyrate and non-esterified fatty acids.
- To evaluate and compare the effects of the surgical procedures (one-step laparoscopic abomasopexy vs. abomasopexy via the right paralumbar fossa) during one-month post-operative follow-up.

3.2. HYPOTHESIS

- To confirm the efficacy of one-step laparoscopic abomasopexy in the treatment of a left displaced abomasum in dairy cows;
- Cows treated via one-step laparoscopic abomasopexy will have an earlier clinical recovery in comparison to those treated with abomasopexy via the right paralumbar fossa laparotomy;
- Verify the lower rate of surgical complications associated with one-step laparoscopic abomasopexy during the short- and long-term evaluation of the procedure; this is because of its minimally invasive nature and limited extent of trauma.

4. CONCLUSION

The displacement of abomasum is frequent in dairy farms around world, and Brazil is not any different than others countries. The most important diagnostic tool remains a careful clinical evaluation, however, when possible, assessment of acid-base and electrolyte status, associated with metabolic profile help to improve the diagnostic and prognostic value.

The one-step laparoscopic abomasopexy was an effective method to treat displaced abomasum under field conditions. The cows treated by this method showed excellent clinical recovery with low incidence of complications. Unfortunately, the feed intake and milk yield after surgery were not evaluated due different management among milk farms, avoiding data collection. Another problem found under field conditions was the need for administration of antibiotics in all cows treated by laparoscopy, because the surgical instruments did not remain sterile during surgery.

5. NEXT STEPS

The blood and urine samples collected during this experiment will be used to measurement of acute phase protein and a manuscript will be written. The additional parameters measured in urine and serum was used to calculate the fractional excretion and a manuscript will be written and submitted to the Journal of Veterinary Clinical Pathology.

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7. CHAPTER 2

One-step laparoscopy for the correction of left abomasal displacement in high-yielding Holstein dairy cows[1]

Abstract

Surgical procedures for the correction of abomasal displacement are one of the most frequently performed in dairy cows, and many surgical techniques have been described since the first cases of this disease were reported in the 1950s. Although no report to date has described the use of one-step laparoscopy in Brazil, the technique has several advantages over the traditional techniques, e.g., better abdominal visualization and minor trauma resulting from the minimally invasive technique. Accordingly, one-step laparoscopy, as described by Christiansen and Barisani, was performed to treat left abomasal displacement in 21 high-yielding dairy cows from two dairy regions of Paraná State. The technique was performed without complications in 12/21 (57.14%) cows. Ruminal (three animals), abomasal (two animals), both ruminal and abomasal (one animal), and splenic (one animal) perforations occurred during surgery. One cow developed pyloric obstruction caused by the toggle bar suture, but early removal restored abomasal flux. Three animals died of different causes. One cow showed recurrence of displacement 1 month after surgery. A third access was necessary in cows that weighed more than 700 kg. One-step laparoscopy is an efficient, fast, and safe technique for the correction of left abomasal displacement.
Key words: dairy cattle, laparoscopy, left abomasal displacement

7.1. Introduction

Abomasal displacement has been defined as the abnormal movement of the abomasum into the abdominal cavity. It is mostly referred to as left abomasal displacement (LAD) when the abomasum is displaced in a left caudodorsal direction between the rumen and abdominal wall (NIEHAUS, 2008). Studies have shown that LAD is 8 to 9 times more likely to occur than right abomasal displacement (SHAVER, 1997).

The pathogenesis of abomasal displacement has not been fully established, and several factors have been associated with disease development (GEISHAUSER, 1995). Although increased ruminal and abomasal production of volatile fatty acids (SVENDSEN, 1970), negative energy balance (SHAVER, 1997), hypocalcemia (CURTIS et al., 1983), ketosis (ROHRBACH et al., 1999), metabolic alkalosis (POULSEN; JONES, 1974), prostaglandins, and endotoxins (VLAMINCK et al., 1985) have been suggested to play a role in disease pathogenesis, no etiologic agent has been experimentally established to contribute to pathogenesis (BARROS FILHO, 2002; ITOH et al., 2011).

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Treatment of LAD has focused on surgical repositioning of the abomasum via several techniques with specific advantages and disadvantages associated with the correction of the acid-base and electrolyte imbalances (BARROS FILHO, 2008). Surgical techniques include right paralumbar omentopexy or the Hannover approach (DIRKSEN, 1961, 1967), left paralumbar omentopexy or the Utrecht approach (LAGERWEIJ; NUMANS, 1962, 1968), ventral paramedian omentopexy (STRAITON; MCINTEE, 1959), percutaneous abomasal fixation (HULL, 1972), percutaneous fixation with toggle bar suture (GRYMER; STERNER, 1982), two-step laparoscopic abomasopexy (JANOWITZ, 1998), and, more recently, one-step laparoscopic abomasopexy (BARISANI, 2004; CHRISTIANSEN, 2004).

One-step laparoscopic abomasopexy has been considered an advancement of the two-step laparoscopic technique, and is characterized by the ventral (and cranial to navel) fixation of a toggle suture by using a “spieker”. Although this technique has been described as being faster, less traumatic, less stressful, and more comfortable (no dorsal recumbence) than the other techniques are (BARISANI 2004; VAN LEEUWEN et al., 2009), no study to date has described its use in Brazil. Therefore, the present study was conducted to describe the outcomes and complications of 21 dairy cows with LAD treated using one-step laparoscopic abomasopexy.

7.2. Material and Methods

This study was performed on 21 Holstein-Friesian dairy cows with LAD. All cows were from high-yielding dairy farms (higher than 8500 kg of milk/cow/305 days) of Arapoti-PR (nine farms; 19 animals) and Fazenda Rio Grande-PR (one farm; two animals).

The diagnosis of LAD was established through clinical examination, drop in milk yield, presence of scant and diarrheic faeces, dehydration (skin turgor and eye position in the orbit), and tympanic and metallic ping on auscultation-percussion in the left paralumbar fossa.

The short-term efficacy (during 1 month) of one-step laparoscopic abomasopexy was evaluated. The surgeries were performed between April 2014 and April 2015 by one surgeon (JHP) with assistance from three others surgeons (RDH, HRD, and IRBF).

One-step laparoscopic abomasopexy was performed according the technique reported by Christiansen (2004) and Barisani (2004). The cows were restrained in yokes and the skin 15 cm ventral to the transverse process and 5 cm caudal to the 13^{th} rib was clipped; the cows were then anesthetized using 10 mL of 2% lidocaine without a vasoconstrictor. Following skin incision, a trocar (9-mm external diameter, 8-mm internal diameter, and 11.5-cm length) was introduced dorsocaudally, perforating the abdominal muscles and peritoneal membrane (fig. 01). The laparoscope (0º, 40-cm length, and 7-mm diameter) was introduced through this port and an air pump (4 L/min, 0.2 bar, and 230 V) was connected. The work port (12-mm diameter and 12-cm length) was introduced under laparoscopic guidance over the 11^{th} intercostal space after clipping and anesthesia. The abomasum was localized (fig. 02), and the dorsal region (next to the greater omentum attachment in the greater abomasal curvature) was perforated (fig. 03) using a cannula. The toggle bar suture was introduced into the abomasum by using a rod (3-mm diameter and 36.5-cm length), and the viscera was then deflated. The thread was tied to the spieker (1-m length and 11-mm diameter), which was inserted between the rumen and the left body wall up to the right ventral paramedian region. The toggle bar suture was exteriorized after a knock in the high extremity of the spieker localized in the left body wall (fig. 05B), and was tied in ventral abdomen using a gauze roll.

Christiansen (2004) described a modified technique. The procedure was performed conventionally until the introduction of the toggle bar suture into the abomasum. At this point, the spieker was introduced into the abdomen without the toggle suture. The ventral abdomen was perforated, and a nylon thread was tied to the ventral extremity of the spieker (fig. 05A), which was then removed out of the abdomen. At this point, one end of the nylon thread was in the ventral paramedian region and the other in the left body wall. The toggle suture was tied to the nylon thread (fig. 06A), and the ventral extremity was pulled (fig. 06B), exteriorizing the toggle bar suture, which was then tied.

This technique was further modified for cows weighing more than 700 kg, because the spieker could not reach the right paramedian side in such heavier cows. A third access over the 10th or 11th intercostal space and 15 cm ventral to the second access was used to introduce the work port and spieker. To move the toggle bar suture ventrally, the thread had to be recovered first (fig. 05A) through the third port by using a hook or a clamp used in the technique described by Janowitz (1998). This step was necessary because the thread was in the second port (fig. 04).

Following surgery, the cows were administered benzathine benzylpenicillin intramuscularly for 3 consecutive days (20000 IU/kg/24 h). Surgical wounds were cleaned with povidone iodine and protected against flies. The toggle bar suture was removed 7 days after surgery.

7.3. Results

Data regarding the animals and techniques used in this work, as well as complications, have been described in table 01. Three animals underwent surgery according to the technique described by Barisani (2004). However, some complications were encountered during that procedure, and hence, the method described by Christiansen (2004) was used. The overall mean duration of surgery was (without the animal's preparation time) 35.04 ± 11.40 min (range, 20 to 60 min).

Three animals died 48, 72, and 120 h after surgery. One animal had fetid gas and green-colored content inside the uterus at necropsy. Another animal had not shown satisfactory improvement following surgery, and necropsy was not performed to discover the cause of death. One animal had dark, fetid, diarrheic feces; pale mucous membrane; and a packed cell volume of 15% 48 h after surgery. Supportive treatment (fluid-therapy and blood transfusion) was not effective, and the cow died. At necropsy, the abomasum was found to have been ruptured at the point of toggle fixation. The cause of abomasal rupture and bleeding was suspected to be a fall, because the owner had reported previous episodes of falling and slips for this animal.

Cow 04 did not recover after surgery, and a blood-gas analysis revealed a diagnosis of metabolic alkalosis with excess of bicarbonate (48 mmol/L 72 h after surgery), possibly due to a pylorus obstruction. The toggle suture was cut off, and the cow's clinical condition improved thereafter.

During laparoscopic port introduction, ruminal (three cases), abomasal (two cases), and ruminal plus abomasal (one case) perforations occurred. Splenic perforation also occurred in one animal during trocar introduction into the abomasum, causing a small hemorrhage. Regardless of these accidents, no complications were observed following surgery.

The technique described by Barisani (2004) was successfully performed in one animal. In cow 09, only one thread of the toggle bar suture was exteriorized during right paramedian perforation. Even with one suture inside and another outside, the abomasum could be fixed in place. This animal has not shown any complications or LAD recurrence during 1 month of monitoring. In cow 10, the toggle bar suture knot was tangled subcutaneously, and the skin was cut to exteriorize the suture.

Cow 08 showed a drop in milk yield 1 month after surgery, and an examination revealed LAD recurrence. The animal was subjected to right-side laparotomy, which revealed an adhesion between the abomasum, rumen, and left body wall, as well as detachment of the parietal peritoneum. Considering these complications, the animal was slaughtered. Subcutaneous emphysema was observed in four animals on the dorsal surface of the transverse process of lumbar vertebrae in one animal and around the surgical wound in three.

7.4. Discussion

One-step laparoscopic abomasopexy has been effectively used to treat LAD under field conditions, despite the use of fragile devices. The procedure can be promptly accomplished by two surgeons. By adopting basic antiseptic care techniques, the cows can be operated on without serious complications such as peritonitis. Laparoscopy also allows visualization of the dorsal rumen, displaced abomasum, spleen, and diaphragm. Moreover, all animals well tolerated the procedure performed in a standing position, using only a yoke restraint and local anesthesia.

This technique has been described as being simpler than two-step laparoscopic abomasopexy, because it can be performed with the animal in the standing position, thereby avoiding aspiration pneumonia, injuries, and uterine and mesenteric torsion (NEWMAN et al., 2008; VAN LEEUWEN et al., 2009). However, the technique also has some disadvantages including the inability to visualize the cranial abdomen and recognize adhesions between the rumen, reticulum, omentum, or right paramedian wall; risk of including the greater omentum in the suture; and abomasal perforation during spieker introduction towards the right paramedian region (NEWMAN et al., 2008).

The average surgical time in this study was higher than that reported in the literature (35 min vs. 20 min) (BARISANI, 2004; CHRISTIANSEN, 2004). This difference could probably be attributed to the number of cases in which a third access port was used in this study (47%), which increased the surgical time. The lower experience of the surgeons in this study compared to those in the literature (21 vs. 200 animals operated) could also have contributed to the increased surgical time.

Surgical accidents during laparoscopic procedures have been described previously (BARISANI, 2004; CHRISTIANSEN, 2004; GNEMMI; MARABOLI, 2006; VAN LEEUWEN et al., 2009). Abomasal perforation can occur when the viscus is highly distended and occupies the cranial portion of the left paralumbar region through which the laparoscopic and work ports were introduced. To avoid this accident, the abomasum was deflated using a Veress needle prior to port introduction. Ruminal perforation can occur when the viscus was distended or next to the left body wall (abomasum partially distended). To avoid this accident, the angle of introduction of the port trocar was set at 45º dorsocaudally (fig. 01) and presurgical left paralumbar fossa massage was given to all the animals.

Gnemmi (2006) has described complications not observed in this study. These include the persistence of the toggle bar suture inside the trocar without moving into the abomasum, the toggle bar suture falling into the abdominal cavity during trocar withdrawal or during trocar rod insertion, release of gas from the abomasum through the trocar during toggle bar insertion, and ventral sliding of the abomasum. Nevertheless, by accurately performing the described movements under laparoscopic guidance, the two surgeons could ensure successful completion of each surgical step.

Abomasal fistula (CHRISTIANSEN, 2004; GNEMMI; MARABOLI, 2006), circumscribed peritonitis, and paramedian myositis at the toggle bar suture fixation site (BARISANI, 2004) were not observed in this study. The adoption of aseptic surgical methods and administration of antibiotics to all animals after surgery could have contributed to the absence of peritonitis, which was observed in the study by Barisani (2004) who did not adopt these practices in all animals.

Using the method described by Barisani (2004) resulted in complications in two animals, as has also been described by Van Leeuwen et al. (2009). These complications included lodging of the toggle bar suture in the subcutaneous tissue and shearing off of threads. The knot joining the threads can produce friction against the big needle, thereby preventing the thread from sliding off the trocar. These complications are known to increase surgical time and hamper correct abomasal fixation.

Clinical and laboratory evaluations performed within 48 h of surgery have been decisive in diagnosing pyloric obstruction caused by the toggle bar suture (KELTON; FUBINI, 1989). The lack of appetite and defecation (VAN LEEUWEN et al., 2009) associated with metabolic alkalosis (48 mmol/L) is also an indication of this surgical complication. However, premature removal of the toggle bar suture can help correct this problem, as reported by Kelton and Fubini (1989) and Van Leeuwen et al. (2009).

Intraabdominal air introduction could induce subcutaneous emphysema (VAN LEEUWEN et al., 2009). In this study, the use of an air pump could not distend the abdominal cavity sufficiently, and hence, its use was discontinued. Apart from the aesthetic appearance of the surgical region, reported by the owners, no other complications were reported until resolution. Spieker introduction induced discomfort and pain in some cows, probably caused by friction of the needle tip against the peritoneum, because of the straight configuration of the needle.

The decision to use a third access port to correct LAD in cows weighing over 700 kg was based on previous experience of difficulty reaching the right ventral paramedian abdomen to fix the abomasum in large cows; nevertheless, left-side fixation does not result in further complications (VAN LEEUWEN et al., 2009). The absence of information in the literature about this modification to the original technique prompted us, on the basis of the experience acquired, to specify this weight (700 kg) as a criterion for deciding which technique to use for surgery.

The greatest risk of using a third access port was ruminal perforation during work port introduction, because at this time, the abomasum has returned to its anatomical position, allowing the rumen to touch the left body wall. The introduction of the work port should be done under laparoscopic guidance to prevent ruminal perforation. In this study, the abomasum could not be fixed on the right paramedian region by using the third access port only in one animal.

Minimally invasive surgical techniques have not ensured permanent abomasal fixation, and the adhesions formed initially have disappeared in about 60% of the cases until the subsequent lactation period (AL-BAYATI, 2011). Christiansen (2004) reported a recurrence rate of 0.019% (three of 152 animals operated), but did not describe how long the observation time was. In this study, two animals had LAD recurrence during the study period—one because of a technical error (fixation on the left paramedian side) and the other because of a lack of adhesion. However, recurrence was not observed in any of the treated cows during the subsequent lactation period.

7.5. Conclusion

One-step laparoscopic abomasopexy has proved efficient in correcting LAD under field conditions. Moreover, although complications previously reported in the literature were observed in this study, these did not affect surgical efficiency. The study findings suggest that the possibility of treating LAD via a faster, safer, and less traumatic procedure justifies the use of expensive laparoscopic equipment.

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Table 01 – Weight, complications and chosen method employed to treat 21 cows with left abomasal displacement by one-step laparoscopic abomasopexy

Animal	**Weight (Kg)**	**Complications**	**Observation**
1	702	Ruminal perforation	Third access required, subcutaneous emphysema
2	750	Ruminal perforation	-
3	518	Ruminal and abomasal perforation	-
4	702	Ruminal perforation	Third access required, pylorus obstruction, toggle bar suture removed 72h following surgery; subcutaneous emphysema
5	795	Abomasal perforation	Third access required, abomasum fixed in left paramedian region; subcutaneous emphysema
6	563	Abomasal perforation	Death due abomasal perforation 120 hours after surgery
7	716	Splenic perforation	Third access required
8	767	difficulty in leading the spieker ventrally	Third access required. Relapsed one month following surgery
9	483	Toggle thread cut off by trocar tip (released internally in abdomen)	Method of Barisani
10	735	Toggle suture remained in subcutaneous tissue	Method of Barisani; death 72h after surgery
11	518	-	-
12	577	-	-
13	681	-	-
14	492	-	-
15	800	-	Third access required
16	767	-	Third access required
17	742	-	Third access
18	490	-	Subcutaneous emphysema
19	577	-	-
20	850	-	Third access required, relapsed 48h after surgery
21	762	-	Method of Barisani

Figure 01 – introduction of a trocar in a 45° angle to avoid abomasal/ruminal perforation.

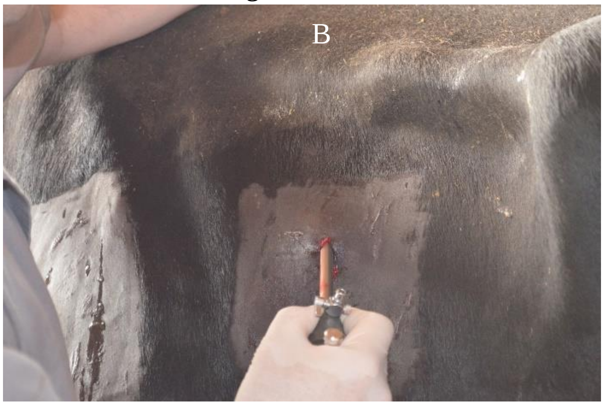


Figure 02 –Laparoscopic inspection and confirmation of abomasal displacement. A, abomasum, R, rumen, S, spleen.

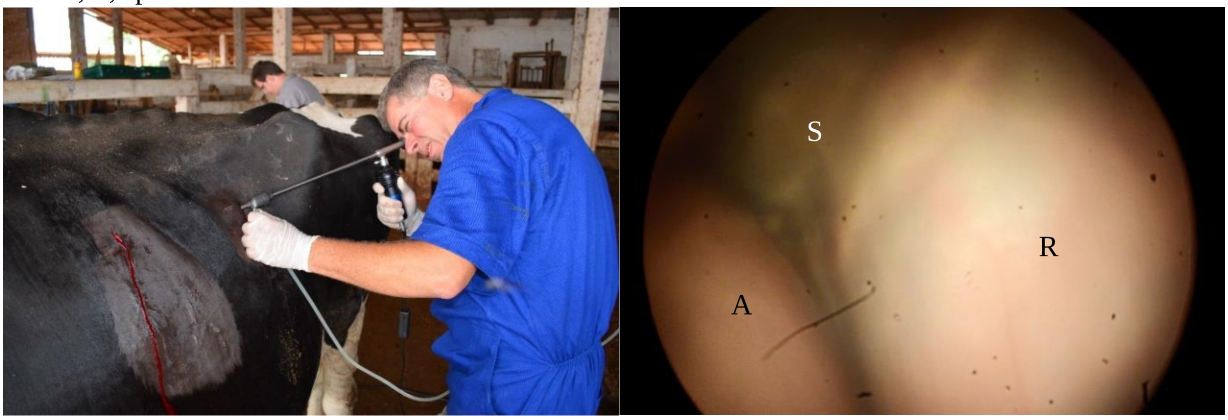


Figure 03 – abomasal deflation under laparoscopic control. The trocar (arrow), which is used to introduce the toggle bar suture inside abomasum is seen via laparoscopy. A, abomasum partially deflated, S, spleen.

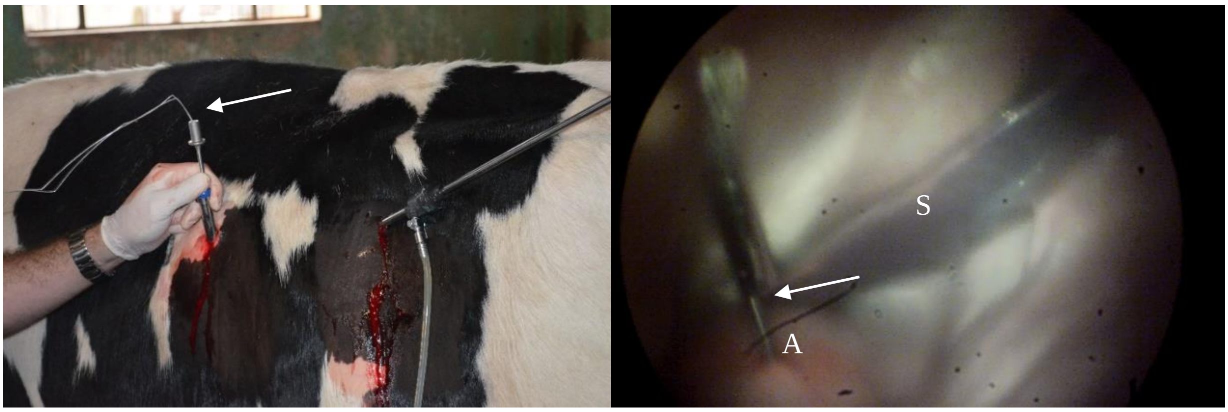


Figure 04 – toggle bar suture recovery in a cow which third access was used. This handling should be performed under laparoscopic control. Note the presence of toggle suture in the hands of surgeon (arrow).

Figure 05 – exteriorization of toggle suture. Figure A shows fixation of nylon thread in the spieker as described by Christiansen (B). Figure B shows exteriorization of toggle suture by Barisani approach.

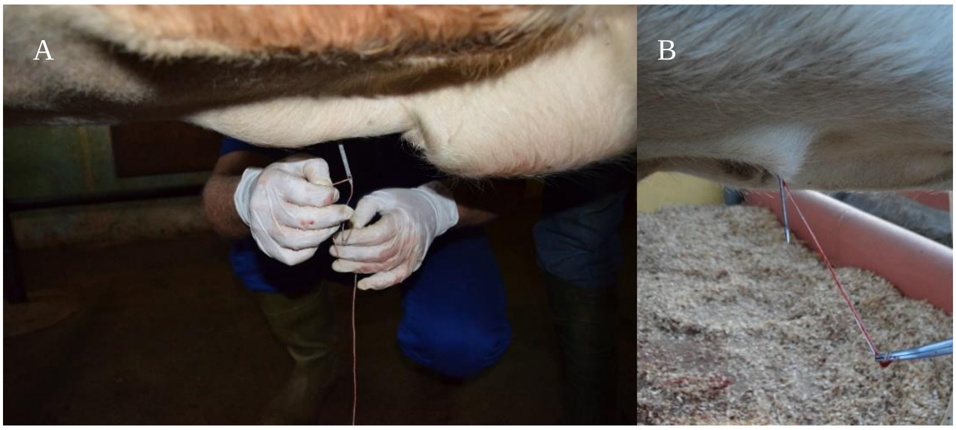
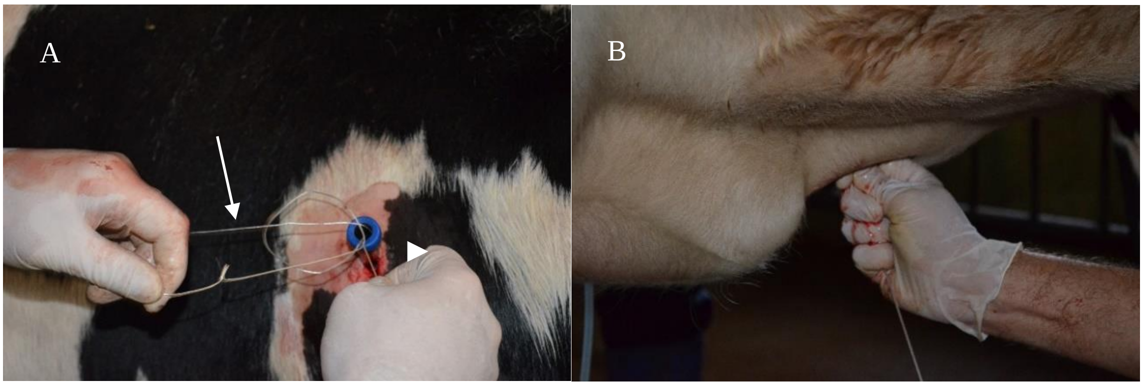


Figure 06 – A, toggle bar suture fixation (arrow) at nylon thread (arrow head). B, toggle suture is exteriorized when nylon thread is pulled at right paramedian region.



8. CHAPTER 3

Surgical complications associated with one-step laparoscopic abomasopexy in dairy cows[2]

João H. Perotta[1*], Hugo R. Dyck[1], Rüdiger D. Ollhoff[2], Júlio A. N. Lisbôa[3], Nilton Vieira[4], Ivan R. Barros Filho[1]

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The one-step laparoscopic abomasopexy was described as faster, less traumatic and less stressful and more comfortable for the cow and the veterinarian in comparison to other approaches (Barisani 2004, van Leeuwen and others, 2009). Particularly in Europe this technique became popular (van Leeuwen and others 2009, Freick and others 2013). Although complications associated with one-step laparoscopic abomasopexy including ruminal and abomasal perforations, peritonitis, abomasal fistula, wire breakage by trocar tip, obstruction of pylorus and fixation of greater omentum by toggle suture (Barisani 2004, Christiansen 2004, Gnemmi 2006, Newman and others, 2008, van Leeuwen and others 2009), the difficulties in performing the procedure under field conditions were not detailed and the involved risks for complications might be underestimated.

This report describes the difficulties and surgical complications associated with the one-step laparoscopic abomasopexy. The procedure was performed in 23 dairy Holstein Friesian cows with left abomasal displacement (LAD), from ten dairy yield farms (higher than 8500 Kg/milk/305 days/per cow) of Parana State, Southern Brazil. Cows were evaluated daily following surgery during one month to verify short-term efficacy of laparoscopic abomasopexy.

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[2] This manuscript was submitted for publication to the “Open Veterinary Journal” as “short communication” and it is formatted according journal´s instruction.

Only two surgeons (JHP & HRD) performed the surgeries. Mean duration of the surgical procedure (from skin incision to skin closure) was 35.04 ± 11.40 minutes (20 to 60 minutes).

A total of 12 procedures (52.17%) had some kind of complication (table 1). During the first step (the optic portal introduction) occurred an accidental perforation of the rumen (four cases; 13.04%), abomasum (two cases; 8.70%) and both organs (one case; 4.34%). During the second step (the trocar introduction into the abomasum) occurred a splenic perforation in one cow (4.34%), causing a slight haemorrhage. subcutaneous emphysema occurred in three cows (13.04%) at the surgical wound site. One cow showed signs of pyloric obstruction 48h following surgery and toggle thread was removed prematurely.

The one-step laparoscopic abomasopexy has been used effectively to treat LAD in farm settings (Barisani 2004, Christiansen 2004, Gnemmi 2006, Freick and others 2013). The duration of the one-step laparoscopic abomasopexy is shorter, taking around 15-20 minutes, but some skill is needed (Christiansen 2004, van Leeuwen and others 2009). The lack of experience of the surgeons associated with the high number of third accesses (46.67%) probably increased surgery time. The decision to use the third access was based on the difficulty of reaching the right side of the ventral abdominal wall in large-framed cows. Even though, abomasopexy on the left side demonstrated good results (van Leeuwen and others 2009). This extra approach allowed the abomasopexy in the correct position.

One-step laparoscopic abomasopexy approach is performed more easily and reliably with two persons (surgeon and assistant). Difficulties in puncturing the abomasum, leading the spieker ventrally and introducing the trocar to create the third access were observed when only one person performed the technique, particularly in large cows. Notably, the risk of ruminal perforation when trocar is introduced into the third access without laparoscopic visual control is high, since the distended abomasum is not more present to create a gap between rumen and body wall. There is a further difficulty in large framed cows to handled laparoscopic instruments due to the larger distances between the different visualization points. In this case, some movements were performed blindly, increasing the risk of accidents.

Abomasal perforation can occur when the abomasum occupies the cranial portion of the left paralumbar fossa due to great distension. This accident can be avoided by deflating the viscera prior to portal insertion plus introduction of the trocar at a 45° angle. Ruminal perforation occurred when the abomasum was only partially distended, allowing close contact of the ruminal wall to the abdominal wall. Using angulated trocar position and massaging the rumen previously avoided this accident. Splenic perforation has not been reported in the literature and occurred in this study due to the difficulty in correctly judging the abdominal depth during laparoscopic visualization.

Obstruction of pylorus was suspected in one cow 48 hours following surgery, Unexpectedly, the animal showed hypokalemia (3.5; 3.4; 2.9; 2.6 mmol.L^{-1} before and 24, 48 and 72h following surgery, respectively), Base Excess (9; 18; 25; 26 mmol.L^{-1}), increased bicarbonate (31.4; 39.3; 48.7; 48 mmol.L^{-1}) and dehydration (PCV of 24; 21; 24; 29%), associated with lack of appetite and absent faeces. These signs are typical of pylorus obstruction (Braun and others 1990, Van Leeuwen and others 2009) and early removal of the toggle suture corrected the obstruction, as reported previously (Kelton and Fubini 1989, van Leeuwen and others 2009).

Peritonitis was not observed in this study, probably because all animals were treated by intramuscular administration of 5,000,000 IU of benzylpenicillin procaine. Although not necessary (van Leeuwen and others 2009), field conditions and owner requirements influenced the choice for antibiotic therapy.

This report detailed difficulties and complications of the one-step laparoscopic abomasopexy which are uncommonly described in literature. Large-framed cows must be treated using third access to avoid left paramedian abomasopexy and relapse. Carrying out the procedure with two surgeons should be taken into account.

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Table 01 – Weight, complications and chosen method employed to treat 23 cows with left abomasal displacement by one-step laparoscopic abomasopexy

Animal	Weight (Kg)	Complications	Observation
1	702	Ruminal perforation	Third access required, subcutaneous emphysema
2	750	Ruminal perforation	-
3	518	Ruminal and abomasal perforation	-
4	702	Ruminal perforation	Third access required, pylorus obstruction, toggle bar suture removed 72h following surgery; subcutaneous emphysema
5	795	Abomasal perforation	Third access required, abomasum fixed in left paramedian region; subcutaneous emphysema; relapsed on week after surgery
6	563	abomasal perforation	Death due abomasal perforation 120 hours after surgery
7	716	Splenic perforation	Third access required
8	767	difficulty in leading the spieker ventrally	Third access required
9	483	Toggle thread cut off by trocar tip (released internally in abdomen)	Method of Barisani
10	735	Toggle suture remained in subcutaneous tissue	Method of Barisani; death 48h after surgery
11	518	-	-
12	577	-	-
13	681	-	-
14	492	-	-
15	800	-	Third access required
16	767	-	Third access required
17	742	-	Third access
18	490	-	Subcutaneous emphysema
19	577	-	-
20	850	-	Third access required, relapsed 48h after surgery
21	762	-	Method of Barisani
22	751	difficulty in leading the spieker ventrally	Third access required; death 48h after surgery
23	780	difficulty in leading the spieker ventrally	Method of Barisani; Abomasum fixed in left paramedian region; relapsed 48h after surgery

9. CHAPTER 4

One-step laparoscopic abomasopexy versus abomasopexy via right paralumbar fossa to treat left abomasal displacement in dairy cows[3]

João H. Perotta[1], Hugo R. Dyck[1], Rüdiger D. Ollhoff[2], Júlio A. N. Lisbôa[3], Nilton Vieira[4], Ivan R. Barros Filho[1]

ABSTRACT.- Perotta, J.H., Dÿck, H.R., Ollhoff, R.D., Lisbôa, J.A.N., Vieira, N. & Barros Filho, I.R. **One-step laparoscopic abomasopexy versus abomasopexy via right paralumbar fossa to treat left abomasal displacement in dairy cows,** Universidade Federal do Paraná, Rua dos Funcionários 1540, Juvevê, Curitiba, PR 80035-050, Brazil. E-mail: perotta@ufpr.br

This study aimed to compare one-step laparoscopic abomasopexy and right paralumbar fossa abomasopexy for the treatment of left displaced abomasum in dairy cows. Thirty Holstein-Friesian dairy cows were randomly placed in two groups: G1, with 15 animals treated by one-step laparoscopic abomasopexy; and G2, with 15 animals treated by right paralumbar fossa ventral abomasopexy. Concentrations of sodium, potassium, chloride, bicarbonate, base excess (BE), pH, strong ion difference (SID), anion gap (AG), glucose, β-hydroxybutyrate (BHBA) and non-esterified fatty acids (NEFA) were measured before (M0) and 24 (M1), 48 (M2) and 72 (M3) hours following surgery. Laparotomy was statistically faster than laparoscopy. Hypochloremia was observed only in G2 at M0. Hypokalemia and hypocalcemia were observed in both groups at M0, increasing after surgery. Metabolic alkalosis in both groups before surgery was characterized by high bicarbonate and BE, which decreased in subsequent time points, as well as blood pH. Glucose concentration was statistically increased and concentrations of NEFA and BHBA were statistically decreased in G2 compared to G1. In G1, NEFA and BHBA decreased significantly following surgery. Both surgical techniques restored abomasal flow and feed intake. Based in acid-base status, one-step laparoscopy showed no additional advantage in comparison with abomasopexy via right paralumbar fossa.

INDEX TERMS: dairy cows, minimally invasive, surgery, acid-basis status, abomasum, cattle

RESUMO.- [Abomasopexia por laparoscopia em um passo em comparação à abomasopexia via laparotomia pelo flanco direito no tratamento do deslocamento de abomaso à esquerda em vacas leiteiras]. Este estudo objetivou comparar as técnicas de abomasopexia por laparoscopia em um passo e abomasopexia por laparotomia pelo flanco direito para o tratamento do deslocamento de abomaso à esquerda (DAE) em vacas leiteiras. Trinta vacas Holandesas Preto e Brancas foram distribuídas de forma aleatória em dois grupos: G1 com 15 animais tratados pela técnica de abomasopexia em um passo; e G2, com 15 animais tratados pela abomasopexia por laparotomia pelo flanco direito. Foram mensuradas as concentrações séricas de sódio, potássio, cloro, bicarbonato, excesso de base (BE), pH sanguíneo, diferença de íons fortes (SID), ânion gap AG), glicose, β-hidroxibutirato (BHBA) e ácidos graxos não esterificados (NEFA). As variáveis foram mensuradas antes da operação e 24, 48 e 72 horas após operação. A laparotomia foi estatisticamente mais rápida do que a laparoscopia no tratamento do DAE.

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Hipocloremia foi observada somente nas vacas do G2 antes da cirurgia. Alcalose metabólica em ambos os grupos antes da operação foi caracterizada pelo aumento do bicarbonato e BE, os quais diminuíram significativamente nos momentos subsequentes, assim como o pH sanguíneo. A concentração de glicose apresentou aumento significativo no G2 em comparação ao G1, enquanto o BHBA e o NEFA estavam estatisticamente diminuídos. Ambas as técnicas restauraram o fluxo abomasal e o consumo de alimentos em ambos os grupos. Baseado no equilíbrio ácido-base, a técnica de laparoscopia não demonstrou vantagens sobre a técnica cirúrgica tradicional.

TERMOS DE INDEXAÇÃO – vacas leiteiras, minimamente invasiva, cirurgia, equilíbrio ácido-base, abomaso, bovinos

9.1. INTRODUCTION

Since first reports of left abomasal displacement (LAD) in the second half of the past century (Begg 1950, Ford 1950), this disease has increased in prevalence and importance worldwide (van Winden & Kuiper 2003). This disorder more often affects dairy cattle, such as Holstein-Friesian, Guernsey and Jersey (van Winden & Kuiper 2003), one month after calving, and increases in older cows (Constable et al. 1992). However, a recent study showed higher incidence in younger cows (Sexton et al. 2007).

Numerous surgical methods have been used to treat LAD, each one with advantages and disadvantages (Seeger et al. 2006). The approaches can be classified as invasive and minimally invasive techniques. Invasive methods include abomasopexy via right paralumbar (Straiton & Mcintee 1959) or left paralumbar fossa laparotomy (Ames, 1968), left paralumbar (Lagerweij & Numans 1962, 1968) or right paralumbar fossa omentopexy (Dirksen 1961, 1967). Left and right paralumbar fossa omentopexy are the most accepted surgical methods due to a low rate of relapse (Bückner 1995). Blind stich (Hull 1972) and toggle-pin suture (Grymer & Sterner 1982) are minimally invasive procedures that were developed as low cost alternatives to more invasive surgical techniques (Hull 1972, Grymer & Sterner 1982), indicated for debilitated or less valuable animals (Barlett et al. 1995).

Janowitz (1998) described a minimally invasive technique using laparoscopy. However, this procedure is performed in two steps and the cow is placed in dorsal recumbency, which is more physically straining for the cow, owner and veterinarian, besides the risk of aspiration pneumonia and trauma (van Leeuwen et al. 2009).

One-step laparoscopic abomasopexy was described in the last decade and can be performed in dorsal recumbency (Newman and others 2005, Babkine et al. 2006) or in standing position (Barisani 2004, Christiansen 2004). The approaches of Christiansen (2004) and Barisani (2004) have been extensively used to treat LAD (Van Leeuwen et al. 2009, Freick et al. 2013) and right abomasal displacement (Freick et al. 2013). However, no randomized controlled trial has been conducted comparing one-step laparoscopic abomasopexy and abomasopexy or omentopexy via right paralumbar fossa.

The objective of this study was to compare outcomes and characteristics achieved of one-step laparoscopic abomasopexy and abomasopexy via right paralumbar fossa laparotomy for the treatment of LAD in dairy cows.

9.2. MATERIAL AND METHODS

The Animal Care and Use Committee of Federal University of Paraná approved this study (056/2013). Thirty Holstein-Friesian cows naturally affected by LAD were used in this experiment. The animals were from nine high-yielding dairy farms (higher than 8500 Kg/milk/305 days/per cow) from the municipality of Arapoti (24° 09' 28" S 49° 49' 37" O), Paraná state, Brazil.

The cows were randomly distributed in two groups:

- Group 1 (G1), with 19 cows, which were subjected to one-step laparoscopic abomasopexy, according to Christiansen (2004). Mean ± SD weight, age and number of lactation of the cows were 639.47 ± 125.87Kg, 4.09 ± 1.33 years old, and 2.20 ± 1.08 lactations, respectively.
- Group 2 (G2), with 15 cows, which were subjected to right paralumbar fossa laparotomy and ventral abomasopexy, according to Baker (1976) and modified by Vieira. Mean ± SD weight, age, and number of lactations of the cows were 618.73 ± 88.55Kg, 4.25 ± 1.83 years old, and 2.27 ± 1.39 lactations, respectively.

Exclusion criteria included cows with severe lameness in one limb (phlegmon, deep sole ulcer and fractures), severe endometritis or severe mastitis with fever, and acute or chronic diarrhea.

All surgical procedures were undertaken from February to April 2015 under field conditions, between 08:00 a.m. and 11:00 p.m. The laparoscopies were performed by one surgeon (JHP) with assistance of two other surgeons (HRD and IRBF). Right flank abomasopexy was performed by one experienced surgeon (NV) with assistance of two others (JHP and HRD).

The diagnosis of LAD was made based in historical drop in milk production and auscultation with percussion and succussion (Dirksen, 1961). After confirmation, the cows were examined for heart and respiratory rates, rectal temperature and ruminal motility (number of rumen contractions per five minutes). Body weight, age, number of births and days after last parturition were recorded.

Blood samples were taken from the jugular vein in tubes without anticoagulant, preoperatively (M0) and 24 (M1), 48 (M2), and 72 hours (M3) after surgery. Three drops of blood without anticoagulant was put in a CG8+ cartridge (i-STAT® Point of Care, Abbott Laboratories, Illinois, USA) as soon as collected and analyzed for partial pressure of carbon dioxide (pCO_2), pH, base excess (BE), bicarbonate, ionized calcium, glucose, and packed cell volume (PCV).

Blood samples were centrifuged and serum was separated and stored at -21 °C until further laboratory analysis. Beta-hydroxybutyrate (BHBA) and non-esterified fatty acids (NEFA) were measured using a commercial test kit (Randox Laboratories Ltd., County Antrim, UK) and using an automated analyzer (BS-200 Chemistry Analyzer, Mindray, Shenzhen, China). Sodium, potassium and chloride ions were measured using an ion-selective electrode (Dimension, Siemens Healthcare GmbH, Munich, Germany).

Strong ion difference and anion gap were calculated using the formulas: $SID = (Na^{+}+ K^{+}) - Cl^{-}$ (Constable et al. 2005) and $Anion\ Gap = (Na^{+}+K^{+}) - (Cl^{-} + HCO_3^{-})$ (Dibartolla 2012).

Results of physical and laboratory exams before surgery (M0) and on three consecutive days after surgery (M1, M2, and M3) were included in the study.

One-step laparoscopy abomasopexy was performed according to Christiansen (2004), using surgical instruments developed for this approach (Dr. Fritz GmbH, Tuttlingen-Möhringen, Germany). The cows were restrained in headgates and the area 15 cm ventral of transverse process and 5 cm caudal to the last rib was clipped and desensitized using 10 mL of 2% lidocaine without vasoconstrictor. An 8.0 mm trocar was introduced dorsocaudally after skin incision, perforating abdominal muscles and peritoneum to introduce the 7.0 mm optic probe. An air pump was connected to this device to create a pneumoperitoneum. In another area over the 11th left intercostal space, after clipping and local anesthesia, a 12 mm working channel was introduced under laparoscopic guidance. The abomasum was located and perforated next to the great omentum at the great abomasal curvature by a 5.0 mm cannula. The toggle bar suture was introduced into the abomasum using a rod, and then the viscera were deflated. The spieker was introduced into the abdomen and the ventral abdominal wall was perforated. A nylon thread was tied at the ventral extremity of the big needle, which was removed from the abdomen. At this time point, one end of the nylon thread was in the ventral paramedian region and the other in the left body wall. The toggle bar suture was tied with nylon thread and the ventral extremity was pulled, exteriorizing the toggle bar suture, which was tied using a gauze roll.

The Christiansen (2004) technique was modified in large-framed cows with weigth ≥700 Kg, because of the impossibility of tying the abomasum at the right paramedian side. To accomplish this, a third access, over the 11th intercostal space, 15 cm ventrally of the second access, was used to introduce the working channel and the spieker. To conduce the toggle bar suture ventrally, first the thread had to be recovered through the third access, using a hook, since the thread was in the second portal. Afterwards, the surgery was completed as described by Christiansen (2004).

Right paralumbar fossa abomasopexy was performed according to Baker (1976) and modified by Vieira (2015). The right flank was clipped and anesthetized with 40 mL of 2% lidocaine without vasoconstrictor at the surgery site. The skin, muscles and peritoneum were incised and the abomasum was located in the left abdomen. The viscus was deflated using a needle attached to a rubber tube. The abomasum was pulled to the right ventral abdomen and an abomasal fold was created using the left hand fingers. An "S" shaped needle with cotton thread was introduced using the right hand from the outside to the inside of the abdomen, passing through the abomasal fold and returning to the outside, again passing through the abomasum. The thread was tied using gauze roll. In both groups, the threads were removed after one week.

All cows from G2 were treated by intra-abdominal administration of 5,000,000 IU of benzylpenicillin procaine immediately before suturing the laparotomy site. Antibiosis continued by intramuscular administration of 5,000,000 IU of benzylpenicillin procaine immediately after surgery and until the end of the study in both groups.

Repeated measure ANOVA with two factors (time and treatment) was used to compare the results. When F was statistically significant, the Bonferroni test was applied to compare the means. Test results were considered significant for values of $P \leq 0.05$. Differences between surgery duration were evaluated by the *t* test. The SigmaStat for Windows 3.1 program (Systat Software Inc., California, USA) was used for all statistical analyses.

9.3. RESULTS

During the study period, 34 cows were operated: 19 by one-step laparoscopic abomasopexy and 15 by abomasopexy via right paralumbar fossa. The surgical procedure was successfully completed in 18 of 19 cows of G1 (94.73%) and in all cows (100%) of G2. In the one animal in which we were not able to complete the surgical procedure, one extremity of the toggle thread remained in the abdominal cavity, preventing abomasal replacement. In this specific animal, the Barisani (2004) method was used. Three cows from G1 were excluded, one due to pylorus obstruction diagnosed 48 h following surgery and two died, 72 h and 120 h after surgery, due to uterine infection and hemorrhage following abomasal perforation.

Hypochloremia was not observed before surgery in G1, but mild hypochloremia was observed in G2 (95.87 $mEq.L^{-1}$; reference value of 97-111 $mEq.L^{-1}$ – Carlson and Bruss 2008) and hypokalemia was noted in both groups (3.35 and 3.43 $mEq.L^{-1}$ for G1 and G2, respectively) (reference value of 3.9-5.8 $mEq.L^{-1}$ - Carlson and Bruss 2008) (Figure 1). Despite increasing to reference values following surgery, no statistical differences between groups and time points inside the groups were observed for chloremia. Cows from G2 were still hypokalemic at M1 (3.78 $mEq.L^{-1}$), although potassium increased significantly in both groups following surgery at M1 (P <0.001) in G1 and at M2 (P<0.001 and P=0.004 for G1 and G2, respectively) and M3 (P<0.001 and p=0.002 for G1 and G2, respectively). However, no statistical difference was observed between G1 and G2 for potassium and sodium ions. Sodium concentration remained in the reference range (132-152 $mEq.L^{-1}$), but decreased significantly at M1 in G1 (P =0.033), and increased significantly at M2 in G2 (P =0.011) (Figure 2). Ionized calcium did not differ statistically between groups (Figure 2). The cows from both groups were hypocalcemic at M0 (1.05 and 1.13 $mmol.L^{-1}$ for G1 and G2 respectively) and M1 (1.13 and 1.16 $mmol.L^{-1}$ for G1 and G2 respectively), increasing at M2 and M3, which differed significantly from M0 in both groups (P<0.001 in G1 for both M2 and M3; P=0.002 and P<0.001 in G2 for M2 and M3, respectively). However, at all time points ionized calcium concentration remained below reference values (2.0-2.8 $mmol.L^{-1}$).

Bicarbonate and BE were elevated in both groups (Figure 3) at M0 (30.65 and 7.2 $mmol.L^{-1}$ for G1; 32 and 8.73 $mmol.L^{-1}$ for G2). In both groups, bicarbonate concentration (P=0.03, P=0.045, P=0.045 for M1, M2 and M3 from G1; P=0.05, P=0.045, P=0.045 for M1, M2 and M3 from G2) and BE (P=0.02, P=0.09, P=0.05 for M1, M2 and M3 from G1; P=0.03, P=0.09, P=0.045 for M1, M2 and M3 from G2) decreased significantly following surgery, but only bicarbonate showed physiologic values (20-30 $mEq.L^{-1}$ - Carlson and Bruss 2008). No statistical difference was found comparing groups for bicarbonate, blood pH, pCO_2, AG and BE (Figures 3, 4, and 5). Data on pH showed statistically significant decrease in G2 following surgery at all time points (P=0.02, p=0.07 and P=0.044 for M1, M2, and M3 respectively) and at M1 (P=0.07) and M2 (P=0.07) in G1 (Figure 4).

Partial pressure of carbonic gas showed values in the physiologic range at all time points of both groups (35-44 mm Hg). Anion gap was slightly lower than physiologic values (14-20 $Meq.L^{-1}$) at M1 in G2 (13.87 $mEq.L^{-1}$). Strong ion difference was higher in G2 compared to G1 at M3 (42.73 x 45.62 $mEq.L^{-1}$; P=0.033). Anion gap, SID and pCO_2 did not differ significantly between time points in both groups and AG and pCO_2 showed no statistical difference between groups (Figures 4 and 5).

Cardiac and respiratory rate, body temperature (data not shown), packed cell volume and ruminal motility (Figure 8) did not differ statistically between groups. No statistical differences in ruminal motility were observed in G2, and in both groups regarding heart and respiratory rate and body temperature. Higher ruminal motility was observed at M3 (P=0.039) compared to M0 in G1. The cows were slightly dehydrated before surgery (Reference value of 22-33% - George et al. 2010), with packed cell volume decreasing significantly in both groups at M1 (P<0.008 and P<0.007 for G1 and G2 respectively), at M2 (P<0.001 for both groups), and at M3 (P<0.001 for both groups).

Glucose increased significantly in G2 (Figure 6) at all time points (p=0.08, p=0.02, p=0.08, p=0.04 for M0, M1, M2 and M3, respectively). Inside groups, only at M1 did glucose differ statistically, in both groups (p=0.04 and p=0.039 for G1 and G2, respectively), being greater than the reference value in G2 (77.13 x 75 $mg.dL^{-1}$).

Beta-hydroxybutyrate (BHBA) increased significantly in G1 compared to G2 at M0 (p<0.001), M1 (p=0.003) and M2 (p=0.024) (Figure 7). NEFA was statistically greater in G1 at all time points (p=0.03, p=0.015, p=0.05, p=0.014 for M0, M1, M2 and M3 respectively), but decreased significantly following surgery, reaching physiologic values (Figure 6). Data from BHBA (p=0.019, p<0.001, p<0.001 for M1, M2 and M3 respectively) and NEFA (p=0.02, p<0.001, p<0.001 for M1, M2 and M3 respectively) of cows from

G1 decreased significantly after surgery, reaching physiologic values (<0.6 mmol.L^{-1}). Data from NEFA of G2 decreased significantly following surgery (p=0.07, p<0.001 for M1, M2 and M3, respectively).

Mean duration of the surgical procedure (from skin incision to the end of surgery) was 35.04 ± 11.40 minutes (20 to 60 minutes) for G1 and 24.67 ± 2.1 minutes (24 to 28 minutes) for G2. Laparotomy was statistically faster than laparoscopy (p=0.006).

Eleven cows from G1 had concurrent diseases, five (33.34%) had mild endometritis and six (40%) had mild lameness in one limb. In this group, one cow (6.67%) was pregnant (seven months) and two calved twins. In G2, seven cows (46.67%) had concurrent diseases, five (33.34%) suffered from mild lameness in one limb and two (13.34%) had mild endometritis. Seven cows (46.67%) were pregnant during LAD, four with five and two with seven months. One cow calved twins.

One cow from G1 relapsed one month after surgery. The animal was operated by right paralumbar fossa laparotomy, but the abomasum could not be replaced due to adhesions and the cow was slaughtered. Third access was performed successfully in seven (46.67%) cows due to large frame (weight ≥ 700 Kg).

9.4. DISCUSSION

The one-step laparoscopic abomasopexy has been used effectively to treat LAD in farm settings (Barisani 2004, Christiansen 2004, Gnemmi 2006, Freick et al. 2013), however all papers describing procedures following Barisani (2004) and Christiansen (2004) are case studies with no controls (van Leeuwen et al. 2009). To our knowledge, this is the first randomized research report comparing this technique with another and the first study evaluating the efficacy of abomasopexy via laparotomy in the right paralumbar fossa.

Obstruction of pylorus was suspected in one cow 48 hours following surgery, which is the most favorable time point for diagnosis (Kelton & Fubini 1989). Unexpectedly, the animal showed hypokalemia (3.5; 3.4; 2.9; 2.6 mmol.L^{-1} for M0, M1, M2 and M3 respectively), BE (9; 18; 25; 26 mmol.L^{-1} for M0, M1, M2 and M3 respectively), increased bicarbonate (31.4; 39.3; 48.7; 48 mmol.L^{-1} for M0, M1, M2 and M3 respectively) and dehydration (PCV of 24; 21; 24; 29% for M0, M1, M2 and M3 respectively), associated with lack of appetite and absent feces. These signs are typical of pylorus obstruction (Braun et al. 1990, van Leeuwen et al. 2009) and early removal of the toggle suture corrected the obstruction, as reported previously (Kelton & Fubini 1989, van Leeuwen et al. 2009).

Peritonitis was not observed in this study, probably because all animals were treated with antibiotics. Although not necessary (van Leeuwen et al. 2009), field conditions and owner requirements influenced the choice for antibiotic therapy.

The duration of the one-step laparoscopic abomasopexy is shorter, taking around 15-20 minutes, but some skill is needed (Christiansen 2004, van Leeuwen and others 2009). Abomasopexy via right paralumbar fossa was significantly faster than one-step laparoscopic abomasopexy. The difference in operating time was influenced by the lack of experience of the surgeon who performed laparoscopy and the lengthy experience (30 years of the surgeon who performed laparotomy. The high number of third access (46.67%) probably further increased surgery time.

The decision to use the third access was based on the difficulty of reaching the right side of ventral abdomen in large-framed cows, even though abomasopexy on the left side demonstrated good results (van Leeuwen et al. 2009). This extra approach allowed the abomasopexy in the correct position.

Cows with LAD developed metabolic alkalosis with hypochloremia, hypokalemia and increased BE, due to partial obstruction of the abomasal passage, keeping bicarbonate in plasma and chloride ions in the gastrointestinal tract. Concomitantly, a compensatory increase in pCO_2 occurs in blood plasma (Braun and others 1988). Hypokalemia occurred because H^+ ions leave the distal tubule cells to titrate bicarbonate, exchanged by K^+ ions that enter the cell, resulting in potassium excretion (Dibartolla & de Morais 2012). Sodium ions are reabsorbed with Cl^- in normochloremic state. But in hypochloremic states, Na^+ is reabsorbed with bicarbonate, maintaining metabolic alkalosis (Monnig 2013).

The usual clinical presentation of cows with LAD was observed in both groups before surgery, with metabolic alkalosis (increased bicarbonate and BE), hypokalemia and hypochloremia. All animals improved regarding acid-base and electrolyte status following surgery, but the treatment approach did not influence the recovery.

Anion gap (AG) is the difference of unmeasured cations (UC) and anions (UA), but the discussion about AG is normally restricted to UA (Constable 2014). This variable is employed to distinguish between hyperchloremic metabolic acidosis (normal AG) and normochloremic metabolic acidosis (increased AG), where protein, ketones bodies and lactate contribute to increase AG (Monnig 2013). Metabolic alkalosis is associated with slight increases in AG due to lactic acid production (Huckabee 1958), but the reviewed literature has meager information about cows with LAD, and variations in AG in cows with displaced abomasum are associated with increased AG (Delgado-Lecaroz et al. 2000) and a marked increase is associated with death (Garry et al. 1988).

Except for a slight decrease at M0 in G2, AG remained within physiologic values. Despite increased ketone bodies in cows from G1, AG did not increase above the reference range. The absence of high values for AG could be explained by rapid diagnosis and treatment, avoiding high production of organic acids, phosphates and sulfates. But, as for plasmatic proteins, these variables were not measured.

Cows with LAD show increased SID due to hypochloremia (Barros Filho 2002), which is accompanied by increased bicarbonate and BE (de Morais & Constable 2012, Barros Filho 2002). In this study, these alterations were observed only in G1. The decrease in SID was not significant and the values returned to the reference range (43 $mEq.L^{-1}$) following abomasum reposition and return of intestinal flow. In G2, increased SID following surgery suggests hypoalbuminemia due to acute phase response to inflammation (de Morais & Constable 2012), since acute phase protein increases following laparotomy (Wittek et al. 2012).

Ketosis is a risk factor for abomasal displacement in cows (Rohrbach et al. 1999) and increased BHBA and NEFA have been reported in cows with displaced abomasum, due to negative energy balance (Rehage et al. 1996). The cows from G1 showed ketosis because they were mostly in the postpartum period, with high body score (fatty cows), which explains the increased BHBA and NEFA. The surgical intervention decreased BHBA and NEFA near to reference values, as described in the literature (Rehage et al. 1996), showing returning food intake.

However, almost half of the cows from G2 were pregnant (46.67%). These animals had not been in negative energy balance and consequently in ketosis, as shown by BHBA and NEFA values. NEFA concentration increases a few days before parturition (Bertics et al. 1992). High infiltration of NEFA in the liver, associated with low carbohydrate concentration, increases ketone body production (Baird 1982). The animals from G2 were not in negative energy balance, which may explain the low NEFA concentration. Glucose concentration was higher in G2 than in G1, and associated with low NEFA concentration may explain the low concentration of BHBA. Nevertheless, NEFA declined significantly following surgery. Probably abomasal displacement induced a temporary and weak fat mobilization, insufficient to increase BHBA, and reposition of LAD permitted food intake and decrease of NEFA.

Hypocalcemia increases risk of LAD due to impairment of abomasal motility and consequently gas accumulation (Massey and others 1993, Shaver 1997). In this study, hypocalcemia was observed in both groups before and 24 h following surgery reinforcing previous findings (Curtis and others 1983, Massey and others 1993). Although ionized calcium was below reference values ($\geq$ 2 $mmol.L^{-1}$), data for ionized calcium from healthy cows obtained using the portable analyzer have had excellent correlation with reference analyzer data (Peiró et al. 2010). The data from this study 48 h after surgery corroborate the findings of Peiró et al. (2010).

A portable analyzer was used to measure different variables with good correlation to the gold standard methods (Peiró et al. 2010, Yildirim et al. 2015). In this study, a portable device was essential to measure the acid-basis status, since the experiment was carried out in field settings, without access to another blood gas analyzer. Thus, this device can be an auxiliary tool in diagnosis and treatment of displaced abomasum.

Dehydration is frequent in cows with LAD due to abomasal atony and consequently accumulation of liquid in the abomasum. Animals with great accumulation of fluid have the most evident increase in PCV (Poulsen 1974). In the present experiment, the short period of time between diagnosis and treatment could explain the mild dehydration found in animals with LAD. Fluid therapy was not performed in these animals. Nevertheless, the cows showed rehydration, since PCV decreased significantly following surgery.

Rehydration, associated with other parameters like bicarbonate, potassium, chloride and BE, confirm that both techniques of abomasopexy reestablished gastrointestinal flow. On the other hand, when these parameters are not normalized, pylorus obstruction should be considered for differential diagnosis.

Cows submitted to two-step laparoscopic abomasopexy typically return to normal milk yield and daily energy intake faster than cows submitted to omentopexy (Seeger et al. 2006), but there is no information about the influence of one-step laparoscopic abomasopexy on these variables. Initially, we aimed to determine milk yield and daily energy intake, but the cows remained in free stalls and some dairy farms did not record individual milk yield during the post-operative period, to this information could not be recorded.

The one-step laparoscopic abomasopexy proved to be a suitable and quick option to treat cows with LAD under field settings, mostly in cows with general disorders, since dorsal recumbency is not necessary. Both techniques reestablished abomasal flow, enabling recovery of food intake and negative energy balance status. However, this experiment showed no additional advantage of one-step laparoscopy in comparison to the abomasopexy via right paralumbar fossa, because both techniques showed similar postsurgical recovery rates. Further studies are needed to establish whether one-step laparoscopic influences milk yield and daily energy intake during the post-operative period.

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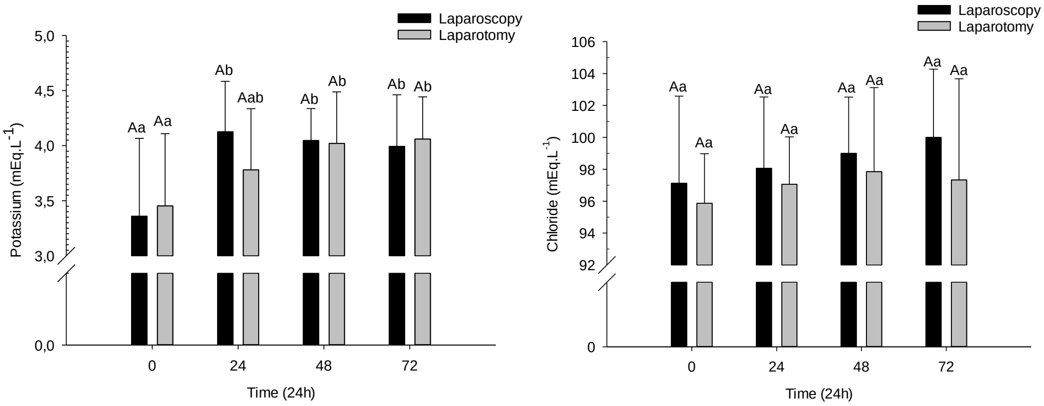

Figure 01- Mean ± standard deviation of Cl^- and K^+ blood concentrations from 30 Holstein cows with left abomasal displacement treated by one-step laparoscopy (laparoscopy; black column; n=15) or abomasopexy via right paralumbar fossa (laparotomy; grey column; n=15) before (0) and during the first three days post-surgery. Different capital letters differ between groups (p≤0.05). Different small letters differ between time points inside groups (p≤0.05).

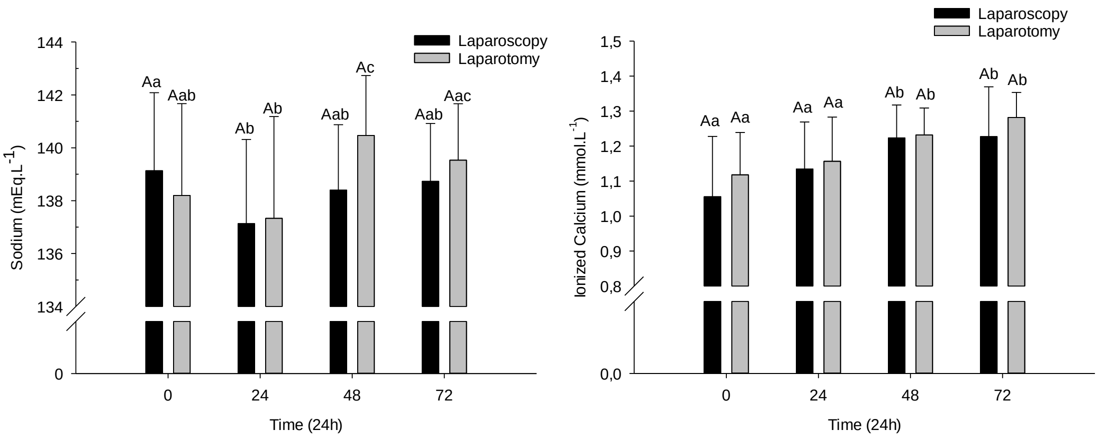

Figure 02 - mean ± standard deviation of ionized calcium and sodium ion blood concentrations from 30 Holstein cows with left abomasal displacement treated by one-step laparoscopy (laparoscopy; black column; n=15) or abomasopexy via right paralumbar fossa (laparotomy; grey column; n=15) before (0) and during the first three days post-surgery. Different capital letters differ between groups (p≤0.05). Different small letters differ between time points inside groups (p≤0.05).

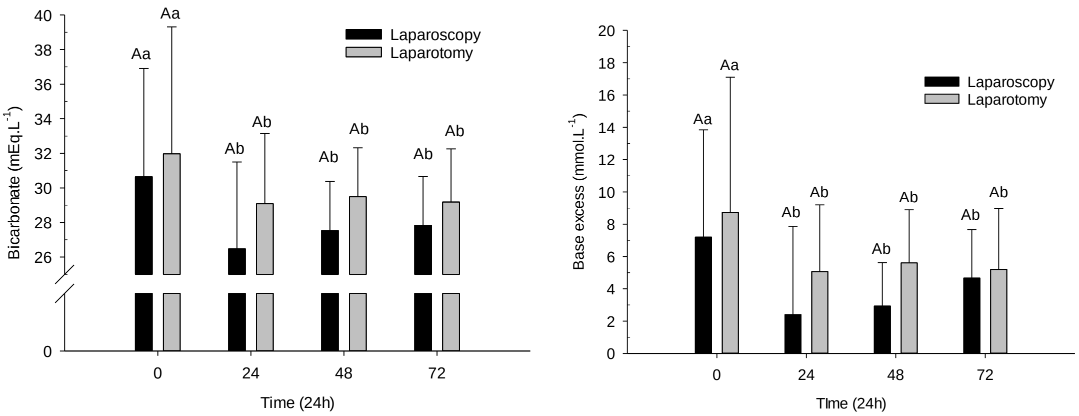

Figure 03 - mean ± standard deviation of bicarbonate blood concentration and base excess from 30 Holstein cows with left abomasal displacement treated by one-step laparoscopy (laparoscopy; black column; n=15) or abomasopexy via right paralumbar fossa (laparotomy; grey column; n=15) before (0) and during the first three days post-surgery. Different capital letters differ between groups ($p \leq 0.05$). Different small letters differ between time points inside groups ($p \leq 0.05$).

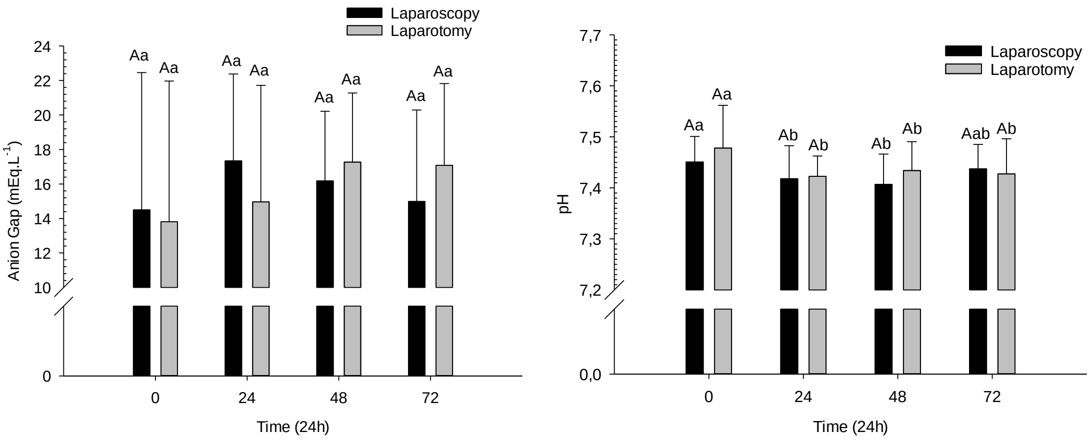

Figure 04 - mean ± standard deviation of plasma pH and anion gap from 30 Holstein cows with left abomasal displacement treated by one-step laparoscopy (laparoscopy; black column; n=15) or abomasopexy via right paralumbar fossa (laparotomy; grey column; n=15) before (0) and during the first three days post-surgery. Different capital letters differ between groups ($p \leq 0.05$). Different small letters differ between time points inside groups ($p \leq 0.05$).

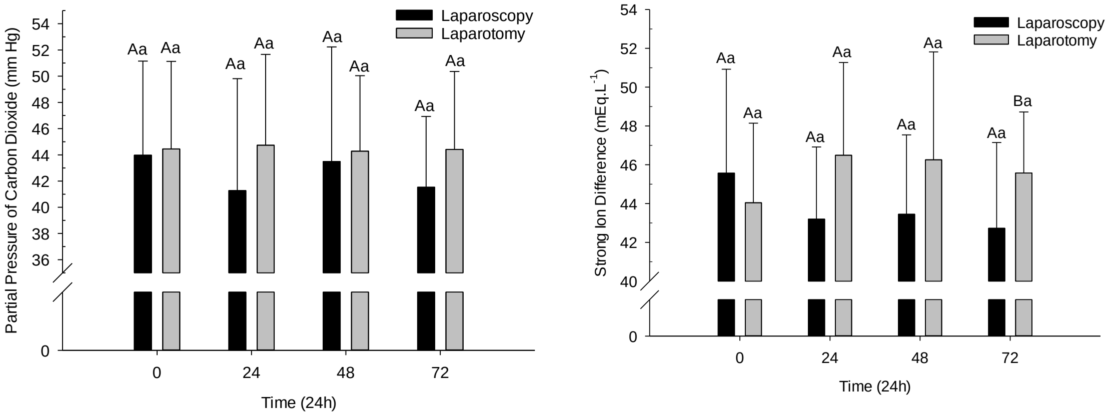

Figure 05 - mean ± standard deviation of partial pressure of carbon dioxide and strong ion difference from 30 Holstein cows with left abomasal displacement treated by one-step laparoscopy (laparoscopy; black column; n=15) or abomasopexy via right paralumbar fossa (laparotomy; grey column; n=15) before (0) and during the first three days post-surgery. Different capital letters differ between groups (p≤0.05). Different small letters differ between time points inside groups (p≤0.05).

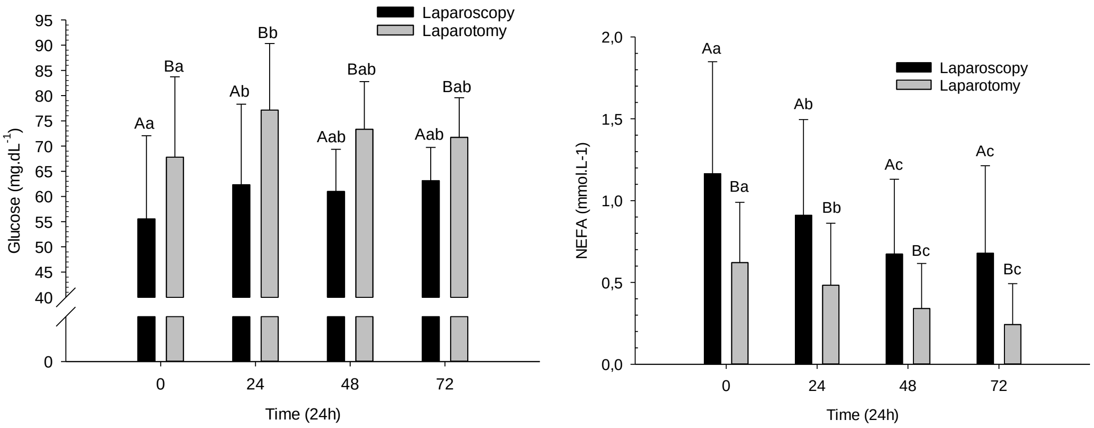

Figure 06 – mean ± standard deviation of glucose and non-esterified fat acid blood concentration from 30 Holstein cows with left abomasal displacement treated by one-step laparoscopy (laparoscopy; black column; n=15) or abomasopexy via right paralumbar fossa (laparotomy; grey column; n=15) before (0) and during the first three days post-surgery. Different capital letters differ between groups (p≤0.05). Different small letters differ between time points inside groups (p≤0.05).

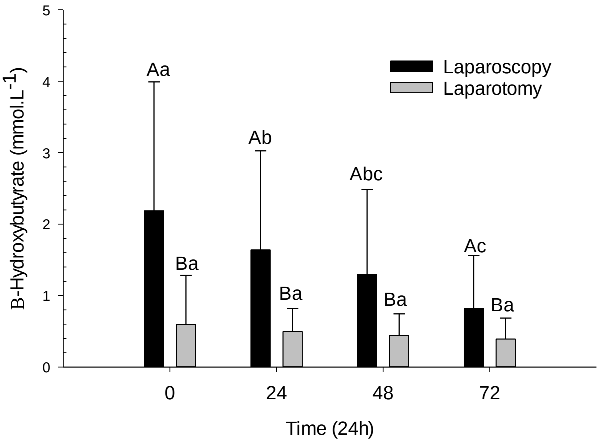

Figure 07 – mean ± standard deviation of β-hydroxybutyrate blood concentration from 30 Holstein cows with left abomasal displacement treated by one-step laparoscopy (laparoscopy; black column; n=15) or abomasopexy via right paralumbar fossa (laparotomy; grey column; n=15) before (0) and during the first three days post-surgery. Different capital letters differ between groups (p≤0.05). Different small letters differ between time points inside groups (p≤0.05).

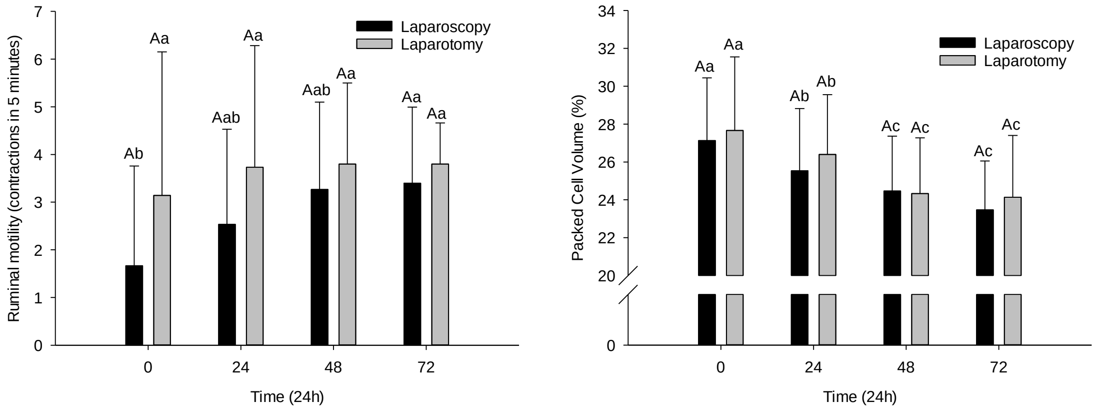

Figure 08 – mean ± standard deviation of packed cell volume and ruminal motility from 30 Holstein cows with left abomasal displacement treated by one-step laparoscopy (laparoscopy; black column; n=15) or abomasopexy via right paralumbar fossa (laparotomy; grey column; n=15) before (0) and during the first three days post-surgery. Different capital letters differ between groups (p≤0.05). Different small letters differ between time points inside groups (p≤0.05).

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SUPPLEMENT

Table 1 – Plasma concentration for sodium (Na+; mmol/L), chloride (Cl-; mmol/L), potassium (K+; mmol/L), ionized calcium (Ca2+; mmol/L), pH, bicarbonate (HCO3-; mmol/L), base excess (BE; mmol/L), anion gap (AG; mmol/L) and measured strong ion difference (SID; mmol/L) from 15 cows with left abomasal displacement and treated by abomasopexy via right paralumbar laparotomy – before surgery (M0)

Animal	Na^+	Cl^-	K^+	Ca^{2+}	pH	HCO_3^-	BE	AG	SID
1	137	99	3.6	0.99	7.5	24	2	17.6	41.6
2	140	99	2.8	1.13	7.47	39.1	16	4.7	43.8
3	143	99	3.5	1.17	7.45	36	12	11.5	47.5
4	139	101	4.6	1.29	7.39	27.9	3	14.7	42.6
5	143	100	4.3	1.04	7.46	26.8	4	20.5	47.3
6	139	86	3.2	0.6	7.5	29.8	7	26.4	56.2
7	139	101	2.7	1.1	7.4	25.7	1	15	40.7
8	143	95	3.5	1.15	7.45	24.4	1	27.1	51.5
9	138	99	3.2	1.13	7.38	30.1	6	12.1	42.2
10	142	91	3	0.84	7.43	30.2	7	23.8	54
11	138	105	2.4	1.2	7.46	32.3	9	3.1	35.4
12	139	100	4.1	1.1	7.39	25.6	1	17.5	43.1
13	132	89	2.7	1.19	7.51	35.4	13	10.3	45.7
14	139	102	4.3	1	7.42	26.1	2	15.2	41.3
15	136	91	2.5	0.9	7.55	46.3	24	1.2	47.5
Mean	**139.13**	**97.13**	**3.36**	**1.06**	**7.45**	**30.65**	**7.2**	**14.71**	**45.36**
SD	**2.95**	**5.44**	**0.7**	**0.17**	**0.05**	**6.26**	**6.65**	**7.91**	**5.47**

Table 2 – Plasma concentration for sodium (Na^+; mmol/L), chloride (Cl^-; mmol/L), potassium (K^+; mmol/L), ionized calcium (Ca^{2+}; mmol/L), pH, bicarbonate (HCO_3^-; mmol/L), base excess (BE; mmol/L), anion gap (AG; mmol/L) and measured strong ion difference (SID; mmol/L) from 15 cows with left abomasal displacement and treated by abomasopexy via right paralumbar laparotomy – 24h after surgery (M1)

Animal	Na^+	Cl^-	K^+	Ca^{2+}	pH	HCO_3^-	BE	AG	SID
1	136	100	4.1	1.19	7.49	20.2	-3	19.9	40.1
2	136	100	4.6	1.32	7.48	25.6	2	15	40.6
3	138	97	4.6	1.16	7.35	27.4	2	18.2	45.6
4	140	100	4.3	1.33	7.42	35.4	11	8.9	44.3
5	140	95	4.2	1.12	7.48	27.7	5	21.5	49.2
6	141	104	4.4	0.86	7.46	23.8	1	17.6	41.4
7	140	101	4.3	1.14	7.31	17	-9	26.3	43.3
8	138	97	3.7	1.18	7.31	26.8	1	17.9	44.7
9	137	101	3.7	1.24	7.39	27.1	2	12.6	39.7
10	139	94	3.8	0.88	7.35	22.2	-3	26.6	48.8
11	136	102	3.3	1.21	7.49	26.9	4	10.4	37.3
12	137	95	4.1	1.14	7.38	27.5	3	18.6	46.1
13	134	93	5	1.14	7.46	33.1	10	12.9	46
14	137	104	4.3	1.1	7.44	22.5	-1	14.8	37.3
15	128	88	3.5	1.01	7.46	33.9	11	9.6	43.5
Mean	**137.13**	**98.07**	**4.13**	**1.13**	**7.42**	**26.47**	**2.4**	**16.72**	**43.19**
SD	**3.18**	**4.46**	**0.46**	**0.13**	**0.06**	**5.03**	**5.47**	**5.48**	**3.73**

Table 3 – Plasma concentration for sodium (Na^+; mmol/L), chloride (Cl^-; mmol/L), potassium (K^+; mmol/L), ionized calcium (Ca^{2+}; mmol/L), pH, bicarbonate (HCO_3^-; mmol/L), base excess (BE; mmol/L), anion gap (AG; mmol/L) and measured strong ion difference (SID; mmol/L) from 15 cows with left abomasal displacement and treated by abomasopexy via right paralumbar laparotomy – 48h after surgery (M2)

Animal	Na^+	Cl^-	K^+	Ca^{2+}	pH	HCO_3^-	BE	AG	SID
1	137	101	3.9	1.23	7.45	22.7	-1	17.2	39.9
2	140	100	3.9	1.34	7.4	27.7	3	12.9	40.1
3	143	97	4.7	1.27	7.34	28.2	3	18.5	46.7
4	139	98	4.4	1.36	7.31	32.8	6	14.6	47.4
5	143	98	4.1	1.12	7.38	29.7	0	22.2	45.4
6	139	102	3.8	1.3	7.51	29.4	7	9.4	38.8
7	139	96	4.3	1.18	7.41	25.6	1	20.7	46.3
8	143	100	3.8	1.23	7.3	27.7	4	18.1	45.8
9	138	102	3.8	1.24	7.42	26.7	3	13.1	39.8
10	142	102	3.8	1.08	7.41	27.2	3	15.6	42.8
11	138	105	3.8	1.35	7.39	25.6	1	12.2	37.8
12	139	91	3.8	1.24	7.39	28.9	4	23.9	52.8
13	132	94	4	1.22	7.44	31.8	8	11.2	43
14	139	100	4.4	1.12	7.47	22.6	-1	20.8	43.4
15	136	99	4.2	1.07	7.48	26.3	3	12.9	39.2
Mean	**138.40**	**99**	**4.05**	**1.22**	**7.41**	**27.53**	**2.93**	**16.22**	**43.28**
SD	**2.47**	**3.53**	**0.29**	**0.09**	**0.06**	**2.85**	**2.69**	**4.38**	**4.14**

Table 4 – Plasma concentration for sodium (Na^+; mmol/L), chloride (Cl^-; mmol/L), potassium (K^+; mmol/L), ionized calcium (Ca^{2+}; mmol/L), pH, bicarbonate (HCO_3^-; mmol/L), base excess (BE; mmol/L), anion gap (AG; mmol/L) and measured strong ion difference (SID; mmol/L) from 15 cows with left abomasal displacement and treated by abomasopexy via right paralumbar laparotomy – 72h after surgery (M3)

Animal	Na^+	Cl^-	K^+	Ca^{2+}	pH	HCO_3^-	BE	AG	SID
1	138	100	3.3	1.25	7.54	29.3	7	12	41.3
2	136	100	4.1	1.39	7.39	27.2	3	12.9	40.1
3	139	97	4.4	1.28	7.41	28.1	4	18.3	46.4
4	140	97	4.5	1.26	7.38	30.5	7	17	47.5
5	138	97	4.4	1.13	7.46	23.2	5	22.2	45.4
6	137	104	3.4	0.88	7.47	31.8	9	4.6	36.4
7	140	103	3.6	1.24	7.42	22.9	-1	17.7	40.6
8	142	103	3.7	1.29	7.44	24.8	1	17.9	42.7
9	139	101	4	1.21	7.4	26	2	16	42
10	139	104	3.6	1.14	7.39	26	2	12.6	38.6
11	143	104	4.9	1.55	7.45	30.3	7	13.6	43.9
12	139	88	3.6	1.24	7.4	28.9	5	25.7	54.6
13	136	99	4.5	1.19	7.52	29.3	7	12.2	41.5
14	140	104	4	1.17	7.47	31.7	9	8.3	40
15	135	99	3.9	1.19	7.42	27.4	3	12.5	39.9
Mean	**138.73**	**100**	**3.99**	**1.23**	**7.44**	**27.83**	**4.67**	**14.90**	**42.73**
SD	**2.19**	**4.28**	**0.47**	**0.14**	**0.05**	**2.82**	**2.99**	**5.25**	**4.42**

Table 5 – Plasma concentration for sodium (Na^+; mmol/L), chloride (Cl^-; mmol/L), potassium (K^+; mmol/L), ionized calcium (Ca^{2+}; mmol/L), pH, bicarbonate (HCO_3^-; mmol/L), base excess (BE; mmol/L), anion gap (AG; mmol/L) and measured strong ion difference (SID; mmol/L) from 15 cows with left abomasal displacement and treated by abomasopexy via right paralumbar laparotomy – before surgery (M0)

Animal	Na^+	Cl^-	K^+	Ca^{2+}	pH	HCO_3^-	BE	AG	SID
1	136	91	3.7	1.09	7.54	34.4	12	14.3	48.7
2	135	93	3.3		7.46	29.5	6	15.8	45.3
3	141	96	3.8	1.09	7.5	26.5	4	22.3	48.8
4	138	96	3.6	1.11	7.43	29.5	6	16.1	45.6
5	140	102	4.1	1.28	7.38	24.4	0	17.7	42.1
6	141	96	2.8	0.97	7.66	44.4	24	3.4	47.8
7	137	90	2.5	1.04	7.52	39.8	18	9.7	49.5
8	140	99	4.2	1.33	7.6	21.1	-4	24.1	45.2
9	139	97	3.6	1.32	7.43	26.1	2	19.5	45.6
10	142	99	4	1.1	7.38	31.4	7	15.6	47
11	139	96	3.7	1.18	7.4	30.9	7	15.8	46.7
12	141	96	3.2	1.13	7.52	37.3	15	10.9	48.2
13	137	97	4.3	1.16	7.37	24.7	0	19.6	44.3
14	128	93	2	0.92	7.49	45.9	23	-8.9	37
15	139	97	3	1.05	7.49	33.7	11	11.3	45
Mean	**138.20**	**95.87**	**3.45**	**1.13**	**7.48**	**31.97**	**8.73**	**13.81**	**45.79**
SD	**3.47**	**3.11**	**0.66**	**0.12**	**0.08**	**7.34**	**8.37**	**8.16**	**3.14**

Table 6 – Plasma concentration for sodium (Na^+; mmol/L), chloride (Cl^-; mmol/L), potassium (K^+; mmol/L), ionized calcium (Ca^{2+}; mmol/L), pH, bicarbonate (HCO_3^-; mmol/L), base excess (BE; mmol/L), anion gap (AG; mmol/L) and measured strong ion difference (SID; mmol/L) from 15 cows with left abomasal displacement and treated by abomasopexy via right paralumbar laparotomy – 24h after surgery (M1)

Animal	Na^+	Cl^-	K^+	Ca^{2+}	pH	HCO_3^-	BE	AG	SID
1	138	95	4.5	1.17	7.4	30.4	6	17.1	47.5
2	137	97	4.6	1.18	7.43	24.9	1	19.7	44.6
3	141	99	3.6	1.07	7.43	25.7	2	19.9	45.6
4	137	96	3.6	1.06	7.49	28	5	16.6	44.6
5	143	104	4	1.29	7.41	27.5	3	15.5	43
6	137	98	3.8	1.18	7.45	26	3	16.8	42.8
7	134	97	4	1.23	7.4	25.9	2	15.1	41
8	139	96	3.6	1.08	7.47	30.2	7	16.4	46.6
9	138	98	3.4	1.43	7.37	25.3	0	18.1	43.4
10	137	91	3.2	0.99	7.46	34.9	11	14.3	49.2
11	141	99	4	1.28	7.36	31	6	15	46
12	139	100	4.1	1.14	7.46	27.5	4	15.6	43.1
13	136	94	4.1	1.22	7.36	28.4	3	17.7	46.1
14	126	97	2.3	0.93	7.43	40	16	-8.7	31.3
15	137	95	3.9	1.1	7.42	30.5	7	15.4	45.9
Mean	**137.33**	**97.86**	**3.78**	**1.16**	**7.42**	**29.08**	**5.07**	**14.97**	**44.05**
SD	**3.85**	**2.96**	**0.56**	**0.13**	**0.04**	**4.06**	**4.13**	**6.75**	**4.10**

Table 7 – Plasma concentration for sodium (Na^+; mmol/L), chloride (Cl^-; mmol/L), potassium (K^+; mmol/L), ionized calcium (Ca^{2+}; mmol/L), pH, bicarbonate (HCO_3^-; mmol/L), base excess (BE; mmol/L), anion gap (AG; mmol/L) and measured strong ion difference (SID; mmol/L) from 15 cows with left abomasal displacement and treated by abomasopexy via right paralumbar laparotomy – 48h after surgery (M2)

Animal	Na^+	Cl^-	K^+	Ca^{2+}	pH	HCO_3^-	BE	AG	SID
1	138	100	5.2	1.27	7.33	27.1	1	16.1	43.2
2	142	100	4.5	1.26	7.44	29.3	5	17.2	46.5
3	141	97	4	1.1	7.41	28.4	4	19.6	48
4	139	99	4.2	1.16	7.44	24.8	1	19.4	44.2
5	143	102	4.2	1.27	7.42	32	8	13.2	45.2
6	141	101	4.2	1.32	7.52	29.5	7	14.7	44.2
7	136	101	4.3	1.28	7.35	25.8	1	13.5	39.3
8	145	99	3.6	1.21	7.45	34.6	11	15	49.6
9	142	102	3.7	1.38	7.44	25.5	2	18.2	43.7
10	138	95	3.6	1.13	7.51	31.5	9	15.1	46.6
11	141	98	3.7	1.31	7.42	31	7	15.7	46.7
12	140		3.9	1.22	7.53	30.7	8		
13	142	98	3.9	1.23	7.38	31.9	7	16	47.9
14	139	81	3.2	1.17	7.45	32	9	29.2	61.2
15	140	97	4.1	1.17	7.42	28.2	4	18.9	47.1
Mean	**140.47**	**97.86**	**4.02**	**1.23**	**7.43**	**29.49**	**5.6**	**17.27**	**46.67**
SD	**2.26**	**5.26**	**0.47**	**0.08**	**0.06**	**2.83**	**3.29**	**4**	**4.9**

Table 8 – Plasma concentration for sodium (Na^+; mmol/L), chloride (Cl^-; mmol/L), potassium (K^+; mmol/L), ionized calcium (Ca^{2+}; mmol/L), pH, bicarbonate (HCO_3^-; mmol/L), base excess (BE; mmol/L), anion gap (AG; mmol/L) and measured strong ion difference (SID; mmol/L) from 15 cows with left abomasal displacement and treated by abomasopexy via right paralumbar laparotomy – 72h after surgery (M3)

Animal	Na^+	Cl^-	K^+	Ca^{2+}	pH	HCO_3^-	BE	AG	SID
1	137	98	5.2	1.3	7.33	27.4	2	16.8	44.2
2	138	98	4.4	1.4	7.41	29.6	5	14.8	44.4
3	143	101	4	1.2	7.38	25.5	1	20.5	46
4	140	104	4.3	1.26	7.34	24.4	-1	15.9	40.3
5	142	101	4.2	1.32	7.4	26.1	2	19.1	45.2
6	140	99	3.9	1.32	7.55	33.3	11	11.6	44.9
7	135	96	4	1.29	7.34	25.6	0	17.4	43
8	141	100	3.8	1.27	7.41	32.3	8	12.5	44.8
9	138	97	4.1	1.39	7.46	28.6	5	16.5	45.1
10	140	99	4.1	1.22	7.49	29	6	16.1	45.1
11	140	100	3.7	1.16	7.54	31	9	12.7	43.7
12	140	98	3.7	1.31	7.42	33	9	12.7	45.7
13	141	99	4	1.28	7.5	28.1	5	17.9	46
14	137	76	3.8	1.34	7.41	34.1	10	30.7	64.8
15	141	94	3.7	1.17	7.43	29.7	6	21	50.7
Mean	**139.53**	**97.33**	**4.06**	**1.28**	**7.43**	**29.18**	**5.2**	**17.08**	**46.26**
SD	**2.13**	**6.34**	**0.38**	**0.07**	**0.07**	**3.08**	**3.76**	**4.74**	**5.56**

Table 9 – Heart rate (HR; beats per min.), respiratory rate (RR; breath per min.), rectal temperature (RT; °C), ruminal motility (RM; contraction in 3 min.), packed cell volume (PCV; %), partial pressure of carbon dioxide (PCO_2; mm Hg) and serum concentration of glucose (GLU; mg/dL), non-esterified fatty acids (NEFA; mmol/L) and β-hydroxybutyrate measured by biochemical method (BHBA; mmol/L) or test strip (bhba; mmol/L) from 15 cows with left abomasal displacement and treated by one-step laparoscopic abomasopexy – before surgery (M0)

Animal	HR	RR	RT	RM	PCV	PCO_2	GLU	NEFA	BHBA	bhba
1	64	46	39.5	0	23	30	31	0.23	0.69	6.2
2	76	28	37.9	2	28	54.1	55	0.41	0.24	3.3
3	80	36	38.6	3	25	52.2	66	0.16	0.60	0.8
4	108	76	38.5	1	30	46.4	83	1.46	2.23	0.4
5	68	44	39.1	5	29	38	73	1.89	4.94	0.5
6	88	36	39.1	2	26	38.4	44	1.23	5.24	2.4
7	84	32	38.7	0	26	41	24	1.28	0.69	5
8	88	44	40.5	1	29	35	40	2.3	3.52	5.2
9	72	48	39.9	0	28	51	63	2.22	3.33	1
10	88	44	39.1	1	30	45.8	49	0.23	0.42	4.1
11	60	24	39.6	0	33	45.6	68	1.01	1.96	3.1
12	68	28	38.8	7	24	42.2	72	0.98	1.68	1.2
13	48	16	38	0	30	43.8	61	1.23	5.12	1.2
14	68	20	38.9	3	20	40.9	45	1.39	0.72	2.6
15	64	28	38.8	0	26	55.2	59	1.45	1.42	2.3
Mean	**74.93**	**36.67**	**39**	**1.67**	**27.13**	**43.97**	**55.53**	**1.16**	**2.19**	**2.62**
SD	**14.77**	**14.73**	**0.68**	**2.09**	**3.31**	**7.18**	**16.51**	**0.68**	**1.8**	**1.84**

Table 10 – Heart rate (HR; beats per min.), respiratory rate (RR; breath per min.), rectal temperature (RT; °C), ruminal motility (RM; contraction in 3 min.), packed cell volume (PCV; %), partial pressure of carbon dioxide (PCO_2; mm Hg) and serum concentration of glucose (GLU; mg/dL), non-esterified fatty acids (NEFA; mmol/L) and β-hydroxybutyrate measured by biochemical method (BHBA; mmol/L) or test strip (bhba; mmol/L) from 15 cows with left abomasal displacement and treated by one-step laparoscopic abomasopexy – 24h after surgery (M1)

Animal	HR	RR	RT	RM	PCV	PCO_2	GLU	NEFA	BHBA	bhba
1	60	40	38.7	0	21	26	43	0.3	0.30	5
2	70	34	38.2	3	24	34.4	83	0.04	0	0.8
3	76	32	37.3	3	23	48.9	76	0.27	0.42	0.4
4	90	48	37.8	5	27	54.6	64	0.89	2.14	0.7
5	68	39	38.3	6	28	37.5	78	1.15	4.07	0.5
6	56	44	39	3	29	33.7	62	2.04	4.13	2.7
7	88	40	38.6	1	25	34.4	43	0.51	0.78	4.8
8	72	60	40.3	3	27	54.9	29	1.37	2.05	5.2
9	60	28	37.7	2	25	45.1	62	1.83	2.03	1
10	68	48	38.5	1	28	40.4	53	0.15	0.37	3.9
11	100	52	39.7	0	31	36.1	67	0.89	1.95	2.8
12	64	28	38.6	6	24	46.7	77	0.95	1.17	0.5
13	72	16	37.6	0	29	45.8		1.1	3.60	1
14	60	28	38.2	2	19	33.1	67	1.16	0.43	2
15	60	20	38.6	3	23	47.6	81	1.02	1.08	2.1
Mean	**70.93**	**37.13**	**38.47**	**2.53**	**25.53**	**41.28**	**63.21**	**0.91**	**1.64**	**2.23**
SD	**12.8**	**12.17**	**0.78**	**2**	**3.29**	**8.53**	**16.18**	**0.58**	**1.39**	**1.76**

Table 11 – Heart rate (HR; beats per min.), respiratory rate (RR; breath per min.), rectal temperature (RT; °C), ruminal motility (RM; contraction in 3 min.), packed cell volume (PCV; %), partial pressure of carbon dioxide (PCO_2; mm Hg) and serum concentration of glucose (GLU; mg/dL), non-esterified fatty acids (NEFA; mmol/L) and β-hydroxybutyrate measured by biochemical method (BHBA; mmol/L) or test strip (bhba; mmol/L) from 15 cows with left abomasal displacement and treated by one-step laparoscopic abomasopexy – 48h after surgery (M2)

Animal	HR	RR	RT	RM	PCV	PCO_2	GLU	NEFA	BHBA	bhba
1	60	20	38.3	3	20	32.7	44	0.08	0.42	5
2	64	18	38.7	5	22	45	64	0.05	0.38	0.9
3	74	40	38.2	3	23	51.9	71	0.06	0.37	0.5
4	92	48	38.1	6	26	66	67	0.77	1.48	0.4
5	84	40	38.1	5	27	49.9	70	1.31	1.19	0.7
6	92	40	39.2	2	26	37.4	60	1.02	3.91	2.1
7	80	44	38.2	2	26	40.5	69	0.63	0.71	1.8
8	86	64	39.2	2	27	41	49	1.38	2.07	4.7
9	76	36	38	1	25	40.7	62	1.04	1.75	0.7
10	80	56	38.7	2	28	43.5	50	0.02	0.44	2.5
11	84	20	38.7	3	27	42.5	56	1.04	0.83	2.4
12	68	28	39.1	6	23	48.5	71	0.51	0.66	0.6
13	68	20	37.9	1	27	47	62	0.8	3.96	1
14	72	28	38.1	2	19	30.8	59	0.83	0.52	1.7
15	72	24	38.3	6	21	35	61	0.56	0.70	1.2
Mean	**76.8**	**35.07**	**38.45**	**3.27**	**24.47**	**43.49**	**61**	**0.67**	**1.29**	**1.75**
SD	**9.73**	**14.12**	**0.45**	**1.83**	**2.9**	**8.74**	**8.35**	**0.46**	**1.19**	**1.44**

Table 12 – Heart rate (HR; beats per min.), respiratory rate (RR; breath per min.), rectal temperature (RT; °C), ruminal motility (RM; contraction in 3 min.), packed cell volume (PCV; %), partial pressure of carbon dioxide (PCO_2; mm Hg) and serum concentration of glucose (GLU; mg/dL), non-esterified fatty acids (NEFA; mmol/L) and β-hydroxybutyrate measured by biochemical method (BHBA; mmol/L) or test strip (bhba; mmol/L) from 15 cows with left abomasal displacement and treated by one-step laparoscopic abomasopexy – 72h after surgery (M3)

Animal	HR	RR	RT	RM	PCV	PCO_2	GLU	NEFA	BHBA	bhba
1	68	48	38.9	4	20	34.4	65	0.09	0.28	2.6
2	76	18	38.7	3	23	45.3	65	0.04	0.28	0.3
3	62	28	37.9	3	22	44.3	73	0.19	0.18	0.4
4	82	48	38.1	4	27	52	74	0.23	0.08	0.4
5	68	36	38.5	3	27	33	65	1.21	1.41	0.4
6	92	40	39.4	1	25	43.6	65	1.14	2.41	0.5
7	68	52	38.7	2	21	35.2	60	0.46	0.41	2
8	84	60	38.8	2	25	36.5	48	1.52	1.40	2.8
9	68	24	38	3	25	42	61	1.33	1.61	1
10	92	76	39.3	3	26	43.5	63	0.04	0.47	2.2
11	52	28	38.8	5	24	44.3	55	1.49	1.13	2.2
12	68	40	38.6	6	23	46.9	67	0.66	0.26	0.7
13	68	32	38.3	3	25	35.5	65	0.7	1.82	2.6
14	62	36	39	2	19	43.7	65	0.66	0.30	0.9
15	68	28	38.8	7	20	42.8	56	0.42	0.25	1.1
Mean	**71.87**	**39.6**	**38.65**	**3.4**	**23.47**	**41.53**	**63.13**	**0.68**	**0.82**	**1.34**
SD	**11.25**	**15.2**	**0.44**	**1.59**	**2.59**	**5.4**	**6.61**	**0.53**	**0.74**	**0.94**

Table 13 – Heart rate (HR; beats per min.), respiratory rate (RR; breath per min.), rectal temperature (RT; °C), ruminal motility (RM; contraction in 3 min.), packed cell volume (PCV; %), partial pressure of carbon dioxide (PCO_2; mm Hg) and serum concentration of glucose (GLU; mg/dL), non-esterified fatty acids (NEFA; mmol/L) and β-hydroxybutyrate measured by biochemical method (BHBA; mmol/L) or test strip (bhba; mmol/L) from 15 cows with left abomasal displacement and treated by one-step laparoscopic abomasopexy – before surgery (M0)

Animal	HR	RR	RT	RM	PCV	PCO_2	GLU	NEFA	BHBA	bhba
1	88	36	38.2	1	24	40.2	40.2	86	0.59	0.21
2	72	28	39.2	0	24	41.8	41.8	60	0.58	0.55
3	80	44	39.7	1	29	34.3	34.3	47	0.92	0.74
4	64	20	38.9	2	24	44.6	44.6	68	0.42	0.28
5	60	56	38.8	0	31	41.1	41.1	70	1.42	0.58
6	56	28	38.7	3	28	39.3	39.3	69	0.41	0.00
7	88	28	40	4	26	49.6	49.6	65	1.26	1.66
8	84	40	38.9	12	29	38.9	38.9	57	0.49	0.20
9	72	24	38.6	5	32	39.3	39.3	87	0.5	0.58
10	68	44	38.5		29	52.7	52.7	57	0.47	0.40
11	64	40	38.8	2	28	49.7	49.7	77	0.28	0.34
12	84	48	39.1	5	22	46.3	46.3	63	0.17	0.64
13	68	60	39.2	3	28	43.7	43.7	70	0.21	0.04
14	48	36	39.3	3	37	61	61	102	0.99	0.15
15	80	32	39.4	3	24	44.3	44.3	39	0.61	2.61
Mean	**71.73**	**37.6**	**39.02**	**3.14**	**27.67**	**44.45**	**44.45**	**67.8**	**0.62**	**0.6**
SD	**12.14**	**11.49**	**0.47**	**3.01**	**3.89**	**6.67**	**6.67**	**15.93**	**0.37**	**0.69**

Table 14 – Heart rate (HR; beats per min.), respiratory rate (RR; breath per min.), rectal temperature (RT; °C), ruminal motility (RM; contraction in 3 min.), packed cell volume (PCV; %), partial pressure of carbon dioxide (PCO_2; mm Hg) and serum concentration of glucose (GLU; mg/dL), non-esterified fatty acids (NEFA; mmol/L) and β-hydroxybutyrate measured by biochemical method (BHBA; mmol/L) or test strip (bhba; mmol/L) from 15 cows with left abomasal displacement and treated by one-step laparoscopic abomasopexy – 24h after surgery (M1)

Animal	HR	RR	RT	RM	PCV	PCO_2	GLU	NEFA	BHBA	bhba
1	84	28	37.9	3	22	46.9	71	0.22	0.15	0.4
2	76	36	37.9	3	28	37.5	81	0.35	0.33	0.7
3	72	28	38.8	2	29	38.9	64	0.98	0.93	1.5
4	84	32	38.3	2	24	36.3	71	0.4	0.50	0.4
5	76	80	38.3	2	28	43.6	76	1.27	0.66	1
6	68	24	38.5	3	27	38.7	84	0.33	0.34	0.8
7	80	36	38.8	1	22	42.5	66	0.61	0.73	1.5
8	80	36	38.3	8	23	41.6	65	0.04	0.30	1.1
9	80	20	37.8	4	30	44.1	79	0.88	0.00	0.9
10	80	44	38.2	7	29	48.9	80	0.49	0.29	0.7
11	76	52	38.7	4	27	55.2	91	0.08	0.34	0.9
12	80	44	38.7	9	22	38.5	60	0.04	0.74	0.9
13	68	40	38.5	5	27	50.8	77	0.11	0.36	0.9
14	88	36	38.5	0	32	60.5	114	0.87	0.48	0.9
15	80	36	38.7	3	26	47	78	0.57	1.26	2.2
Mean	**78.13**	**38.13**	**38.39**	**3.73**	**26.4**	**44.73**	**77.13**	**0.48**	**0.49**	**0.99**
SD	**5.63**	**14.17**	**0.33**	**2.55**	**3.16**	**6.92**	**13.20**	**0.38**	**0.32**	**0.46**

Table 15 – Heart rate (HR; beats per min.), respiratory rate (RR; breath per min.), rectal temperature (RT; °C), ruminal motility (RM; contraction in 3 min.), packed cell volume (PCV; %), partial pressure of carbon dioxide (PCO_2; mm Hg) and serum concentration of glucose (GLU; mg/dL), non-esterified fatty acids (NEFA; mmol/L) and β-hydroxybutyrate measured by biochemical method (BHBA; mmol/L) or test strip (bhba; mmol/L) from 15 cows with left abomasal displacement and treated by one-step laparoscopic abomasopexy – 48h after surgery (M2)

Animal	HR	RR	RT	RM	PCV	PCO_2	GLU	NEFA	BHBA	bhba
1	76	28	37.7	3	22	50.3	66	0.15	0.00	1.2
2	84	32	38.3	6	25	42.7	72	0.33	0.26	0.8
3	72	32	38.3	2	29	44.8	58	0.55	1.14	1.6
4	76	36	38	2	22	36.9	71	0.37	0.49	0.5
5	88	64	38.1	1	28	49.5	74	0.71	0.55	1.1
6	56	28	38.5	6	26	36.5	72	0.47	0.45	0.7
7	76	40	39.1	3	20	47.8	60	0.22	0.32	0.9
8	84	24	37.8	7	23	50.1	63	0.02	0.00	0.9
9	68	20	37.7	4	29	37.2	81	0.85	0.26	0.9
10	76	44	38.2	4	27	39.4	73	0.14	0.50	0.9
11	80	44	38.8	5	25	48.3	90	0.03	0.39	1.2
12	80	56	38.5	5	21	37.1	73	0.05	0.44	1.3
13	68	56	39.2	3	24	53.8	82	0.03	0.38	1
14	80	28	39	3	22	46.3	76	0.61	0.48	0.9
15	80	48	38.7	3	22	43.5	89	0.58	0.98	1.7
Mean	**76.27**	**38.67**	**38.39**	**3.8**	**24.33**	**44.28**	**73.33**	**0.34**	**0.44**	**1.04**
SD	**7.92**	**13.06**	**0.49**	**1.7**	**2.94**	**5.76**	**9.44**	**0.27**	**0.3**	**0.32**

Table 16 – Heart rate (HR; beats per min.), respiratory rate (RR; breath per min.), rectal temperature (RT; °C), ruminal motility (RM; contraction in 3 min.), packed cell volume (PCV; %), partial pressure of carbon dioxide (PCO_2; mm Hg) and serum concentration of glucose (GLU; mg/dL), non-esterified fatty acids (NEFA; mmol/L) and β-hydroxybutyrate measured by biochemical method (BHBA; mmol/L) or test strip (bhba; mmol/L) from 15 cows with left abomasal displacement and treated by one-step laparoscopic abomasopexy – 72h after surgery (M3)

Animal	HR	RR	RT	RM	PCV	PCO_2	GLU	NEFA	BHBA	bhba
1	72	36	37.7	2	21	51	77	0.13	0.20	0.4
2	92	30	38.5	4	27	47.1	71	0.33	0.22	0.4
3	68	36	39.1	5	28	43.1	55	0.47	1.21	1.9
4	68	36	38.6	3	20	45.5	69	0.03	0.28	0.6
5	88	80	38.3	5	29	42.6	66	0.51	0.49	0.8
6	68	24	38.6	4	25	38	70	0.31	0.49	0.7
7	80	40	38.8	4	20	47.7	64	0.11	0.15	0.7
8	80	40	38.8	4	22	51.7	67	0.01	0.30	1.2
9	64	28	37.8	4	29	39.8	81	0.79	0.13	0.6
10	72	40	38.3	4	27	37.6	74	0.03	0.00	0.6
11	84	44	38.4	5	25	36.2	87	0.05	0.48	1
12	84	40	38.4	3	20	50.7	67	0.04	0.62	1.1
13	72	64	39.2	3	23	36.6	80	0.05	0.44	0.6
14	80	28	38.7	3	23	54.3	75	0.15	0.24	0.7
15	84	32	38.4	4	23	44.3	73	0.62	0.63	1.4
Mean	**77.07**	**39.87**	**38.51**	**3.8**	**24.13**	**44.41**	**71.73**	**0.24**	**0.39**	**0.85**
SD	**8.48**	**14.51**	**0.41**	**0.86**	**3.27**	**5.95**	**7.84**	**0.25**	**0.29**	**0.41**

Table 17 – Age and body weight from 30 cows with left abomasal displacement and treated by one-step laparoscopic abomasopexy (group A) or abomasopexy via right paralumbar fossa (group B).

Animal – group A	**Age (years)**	**Weight (Kg)**	**Animal – group B**	**Age (years)**	**Weight (Kg)**
1	4.9	702	1	7	688
2	2	518	2	2.5	615
3	3.2	577	3	5.3	622
4	4.6	681	4	7	651
5	4.8	750	5	6.2	600
6	2.1	492	6	2.9	548
7	4.5	767	7	2	548
8	5.5	800	8	2.3	442
9	6	716	9	4.5	659
10	4	767	10	6.6	822
11	5	795	11	3.8	702
12	3	518	12	3.4	518
13	4.8	742	13	5.1	651
14	2.3	490	14	2.9	600
15	2.4	577	15	2.3	585

Universidade Federal do Paraná
Setor de Ciências Agrárias
Comissão de Ética no Uso de Animais – CEUA SCA

CERTIFICADO

Certificamos que o protocolo no. 056/2013, referente ao projeto "Avaliação de abomasopexia por laparoscopia em um passo sobre produção leiteira, consumo de alimentos, equilíbrio ácidobase e eletrolítico e parâmetros bioquímicos em vacas leiteiras com deslocamento de abomaso à esquerda", sob a responsabilidade de Ivan Roque de Barros Filho, na forma em que foi apresentado (uso de 40 vacas), foi aprovado pela Comissão de Ética no Uso de Animais do Setor de Ciências Agrárias, em reunião realizada dia 06 de novembro de 2013.

CERTIFICATE

We certify that the protocol number 056/2013, regarding the project "Evaluation of the laparoscopic technique of abomasopexy in one step on the milk production, feed consumption, acid-base and electrolyte balance and biochemical parameters in dairy cows with left abomasal displacement", under Ivan Roque de Barros Filho's supervision, in the terms it was presented (use of 40 cows), was approved by the Animal Use Ethics Committee of the Agricultural Sciences Campus of the Universidade Federal do Paraná (Federal University of the State of Paraná, Southern Brazil) during session on November 06, 2013.

Curitiba, 20 de novembro de 2013.

Patrick Schmidt
Presidente

Ricardo Guilherme D´Otaviano
de Castro Vilani
Vice-Presidente

Comissão de Ética no Uso de Animais
Setor de Ciências Agrárias
Universidade Federal do Paraná.