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Intraoperative fluid therapy for video-assisted ovariohysterectomy in dogs

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ABSTRACT

Background: Intraoperative fluids are still poorly studied in veterinary medicine. In humans the dosage is associated with significant differences in postoperative outcomes.
Objectives: The aim of this study is to verify the influence of three different fluid therapy rates in dogs undergoing video-assisted ovariohysterectomy.
Methods: Twenty-four female dogs were distributed into three groups: G5, G10, and G20. Each group was given 5, 10, and 20 mL·kg^{-1}·h^{-1} of Lactate Ringer, respectively. This study evaluated the following parameters: central venous pressure, arterial blood pressure, heart rate, respiratory rate, temperature, acid-base balance, and serum lactate levels. Additionally, this study evaluated the following urinary variables: urea, creatinine, protein to creatinine ratio, urine output, and urine specific gravity. The dogs were evaluated up to 26 h after the procedure.
Results: All animals presented respiratory acidosis during the intraoperative period. The G5 group evidenced intraoperative oliguria (0.80 ± 0.38 mL·kg^{-1}·h^{-1}), differing from the G20 group (2.17 ± 0.52 mL·kg^{-1}·h^{-1}) (p = 0.001). Serum lactate was different between groups during extubation (p = 0.036), with higher values being recorded in the G5 group (2.19 ± 1.65 mmol/L). Animals from the G20 group presented more severe hypothermia at the end of the procedure (35.93 ± 0.61°C) (p = 0.032). Only the members of the G20 group presented mean potassium values below the reference for the species. Anion gap values were lower in the G20 group when compared to the G5 and G10 groups (p = 0.017).
Conclusions: The use of lactated Ringer's solution at the rate of 10 mL·kg^{-1}·h^{-1} seems to be beneficial in the elective laparoscopic procedures over the 5 or 20 mL·kg^{-1}·h^{-1} rates of infusion.

Keywords: Dogs; crystalloids; lactated Ringer's solution; videosurgery; abdominal perfusion pressure

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Conflict of Interest
The authors declare no conflicts of interest.

Author Contributions
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INTRODUCTION

Anesthetic and surgical procedures commonly change the normal mechanisms of fluid homeostasis, making imperative the administration of the perioperative fluid therapy [1]. Therefore, the decrease or end of fluid administration can be as important as the start or increase of this process [2]. As a result, there is a concern involving the determination of the adequate rate of fluid therapy for animals subjected to procedures that are increasingly used in veterinary medicine, such as videosurgery.

In particular, videosurgical procedures promote differentiated conditions for anesthesia management since the increase in intra-abdominal pressure (due to the establishment of the pneumoperitoneum) may compromise the cardiovascular and respiratory functions of the patients [3], as well as their renal blood flow [4,5] serum creatinine levels, and urine output [5].

Fluid therapy rates should be individualized and take into account the particular needs of each patient, including its volume, type of solution used, which compartment needs volume replacement, and the surgical procedures performed [6]. The previous conventional guideline that recommended the administration of 10 $mL.kg^{-1}.h^{-1}$ was abandoned since it was considered excessive [2]. Currently, in veterinary medicine, fluid rate recommendation for low-risk procedures is 5 $mL.kg^{-1}.h^{-1}$ for dogs, therefore minimizing the risks related to hypervolemia [1,6] such as edema and compromised respiratory function, decrease in intestinal motility, decrease in tissue oxygenation, increase in infection rates, decrease in hematocrit and total protein content, and reduction in body temperature [7]. High volumes of crystalloid administration were associated with glycocalyx shedding and a higher inflammatory response [8]. However, some authors [9] considered the liberal fluid therapy beneficial for patients free of severe systemic alterations during low-risk surgeries. Silverstein et al. [10] assessed the effects of fluid administration on the microcirculation of healthy anesthetized dogs. The density of vessels ≥ 20 μm in diameter was higher for the total and perfused vessels in dogs that received 20 $mL{\cdot}kg^{-1}{\cdot}h^{-1}$ of LRS. These larger vessels are most likely arterioles and venules critically important for organ perfusion. Further research is required to evaluate the clinical importance of these findings.

The administration of intraoperative fluids in veterinary medicine are a controversial topic due to many unsupported opinions regarding the optimal rate of administration, which presents great gaps in the field [11]. Shin et al. [12] demonstrated that in humans the dosage is associated with significant differences in the postoperative outcomes and Holte [13] stressed out the increasing need of rational fluid administration for laparoscopic surgeries. Therefore, the aim of this study was to analyze the influence of three different fluid therapy rates (restrictive, conventional, and liberal) on a series of cardiovascular parameters, acid-base status, and variables related to the urinary system function, in female dogs undergoing video-assisted ovariohysterectomy (OH), in order to indicate the best fluid rate for this situation.

MATERIALS AND METHODS

The study was approved by the Ethics Committee on the Use of Animals (protocol number 1119160315), and the animals were obtained by contacting non-governmental organizations. The procedures were performed on dogs that had already been adopted and all the dogs were enrolled after obtaining their owners written consent.

The animals were taken to the animal hospital 24 h before the procedure. Twenty-four healthy mixed-breed female dogs, weighing 16.4 ± 2.88 kg, were admitted for video-assisted OH and were randomly assigned to receive one of three treatments consisting of the administration of intravenous (IV) lactated Ringer's solution at a rate of 5 $mL \cdot kg^{-1} \cdot h^{-1}$ (G5), 10 $mL \cdot kg^{-1} \cdot h^{-1}$ (G10), and 20 $mL \cdot kg^{-1} \cdot h^{-1}$ (G20).

The time points for the evaluations were (**Supplementary Table 1** and **Supplementary Fig. 1**): T0, corresponding to basal data; T1, corresponding to 15 min after premedication; T2, corresponding to the moment after anesthetic induction and immediately after neuromuscular block and anesthetic depth adjustment (1.5–1.8%, end-tidal isoflurane concentration [ETiso]); T3, corresponding to the beginning of surgery; T4, corresponding to the moment immediately after the pneumoperitoneum was stablished; T5, corresponding to 5 min after the establishment of the pneumoperitoneum; T6, before pneumoperitoneum drainage; T7, at the end of the surgery; T8, corresponding to extubation point; and T9, corresponding to 24 h after the end of the surgery.

The animal health status was assessed through clinical and laboratorial evaluation. The latter included red blood cell count, leucogram, total protein, platelets count, and biochemical tests (creatinine, urea, albumin, alanine transaminase, and alkaline phosphatase). The serum lactate level was measured in a blood sample (0.2 mL) drawn from the cephalic vein and the urine was collected by urethral catheterization, with a Foley catheter (8 Fr) (Foley catheter, Solidor, Brazil) in order to analyze urinary output, urinary protein to creatinine ratio (P/C ratio), urine specific gravity, and the protein content in the urine. The Foley catheter was kept in place for the next three days for further analyses. All the results obtained for all the variables mentioned above were used to confirm the health status of the patients and used as baseline data (T0).

The feeding of the dogs was suspended for eight hours before the procedure, but water was provided. On the day of the procedure, after antisepsis, an intravenous catheter (20G) (Intravenous catheter, Solidor) was inserted in the right cephalic vein for fluid therapy administration and in the left cephalic vein for the blood sampling required for the assessment of the lactate level.

Subsequently, an intravenous catheter (18G) (Intravenous catheter, Solidor) was placed in the right jugular vein to assess the central venous pressure (CVP) according to a correction factor established by Aguiar et al. [14], in which 0.51 cmH_2O is subtracted from the reading obtained with a peripheral catheter to estimate the CVP value. The auricular artery was accessed with a 24G intravenous catheter (Intravenous catheter, Solidor) that was connected to a pressure transducer positioned at the heart level and connected to a multiparametric monitor (LifeWindow 6000, Digicare Biomedical Technology, Inc., USA) to evaluate the mean (MAP), systolic (SAP), and diastolic (DAP) arterial blood pressure.

Blood (1 mL) for the determination of blood gas and electrolyte contents was drawn from the same artery with a syringe containing lithium heparin, and anaerobically stored until the analyses are performed (up to 2 h). Blood gas and electrolytes were also evaluated 24 hours after the surgery. For this purpose, a blood sample was collected straight from the femoral artery.

After the catheter insertion and assessment of the basal values (T0), the dogs received intramuscularly tramadol hydrochloride (5 $mg \cdot kg^{-1}$) and acepromazine (0.05 $mg \cdot kg^{-1}$; Acepran®, Vetnil, Brazil) as premedication. Fluid therapy was initiated following anesthesia

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induction (at the rates pre-established for each group using a peristaltic infusion pump [Med Pump MP 20, Celm, Brazil]) and stopped at the extubating time.

Anesthesia induction was performed by administration of propofol (Propovan®, Cristália, Brazil), provided in order to enable endotracheal intubation. General anesthesia was maintained with isoflurane (Isoforine®, Cristália) at an ETiso between 1.5% and 1.8%. The animals were mechanically ventilated with a tidal volume of 10 mL·kg^{-1} and inspiration to expiration ratio (I:E) of 1:2. In order to achieve this ratio, atracurium (0.2 mg·kg^{-1}, IV; Tracur®, Cristália) was administered after anesthesia induction. The respiratory rate (*f*) was adjusted during anesthesia to maintain an end-tidal partial pressure of carbon dioxide ($ETCO_2$) of 35–45 mmHg, measured by capnometry. This was accomplished by using a Sidestream CO_2 sensor connected to a multiparametric monitor for the analysis of the expired gases (LifeWindow 6000, Digicare Biomedical Technology, Inc.).

The animals received supplementary perioperative analgesia with fentanyl citrate 2.5 μg·kg^{-1} (IV) in cases where the animal presented an increase in heart rate (HR) or MAP over 30% above the basal values. The T3 values were considered as baseline for the assessment of the perioperative nociceptive stimulus. After the surgery, meloxicam (0.1 mg·kg^{-1}, SID; Maxicam®, Ourofino, Brazil), dipyrone, and hyoscine (25 mg·kg^{-1}, TID; Buscofin®, Agener União, Brazil) were administered subcutaneously for 2 days as post-surgery analgesia.

All the OH were performed by a video-assisted method with two portals, according to the technique described by Brun [15] in a 12 mmHg-pressured pneumoperitoneum, always performed by the same surgeon. Before the beginning of the insufflation of the abdominal cavity, the Veress needle attached to the CO2 insufflator was introduced through the abdominal wall to obtain the baseline values of intra-abdominal pressure (IAP). Abdominal perfusion pressure (APP) was evaluated by using the values of IAP and MAP (APP = MAP – IAP). The values obtained in T3 were considered baseline for this variable.

A multi-parameter monitor was used to record HR, *f*, SAP, DAP, MAP, SpO_2, CVP, and rectal temperature (T°C). All these variables were measured from T0 to T8. At T9, only HR, *f*, and T°C were measured. $ETCO_2$ and ETiso were measured between T2 and T7.

Arterial blood gases, electrolytes, and other variables, including arterial oxygen partial pressure (PaO_2) (measured in mmHg), arterial carbon dioxide partial pressure ($PaCO_2$) (also in mmHg), sodium bicarbonate (HCO_3^-), base excess (BE) or deficit, sodium (Na^+), potassium (K^+), chloride (Cl^-), Anion gap (AG) (all measured in mmol/L), arterial oxygen saturation (SaO_2) (%), and pH were measured at T0, T2, T4–T9. Serum lactate (mmol/L) was measured at T0, T2, T4–T6, T8, and T9.

The urine output (UO) was measured at T0, T8, and T9. At T0 and T9, 10 mL of urine were also sampled to check urine specific gravity and P/C ratio. At the same time periods, 4 mL of blood were sampled to measure serum creatinine and urea. A transurethral Foley catheter (Foley catheter, Solidor) was positioned at the entrance of the bladder for UO measurement (in mL·kg^{-1}·h^{-1}), which was fully emptied and closed. All dogs remained in the animal hospital and were monitored during the 26 h post procedure.

Statistical analysis was performed using the IBM SPSS Statistics 20.0 package (IBM Corp., USA). The Shapiro-Wilk test tested the normality of data. The analysis of variance test with

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Tukey's test or *post hoc* test evaluated variables that presented normal distribution. The significance level used for all tests was 5%.

RESULTS

No dog from any group presented any complication during surgery and no additional analgesia was required during this period. The mean surgical time was 48.5 ± 10.6 min, while the fluid therapy time, in min, was 86.5 ± 16.91, 85.12 ± 13.5, and 85.62 ± 21.25, for G5, G10, and G20, respectively, without differences between the groups ($p = 0.987$). ETiso was 1.56 ± 0.13% on G5, 1.58 ± 0.15% on G10, and 1.57 ± 0.09% on G20, with no differences between the groups. The weight of the animals (G5, 17.7 ± 3.0 kg; G10, 14.5 ± 2.9 kg; and G20, 16 ± 3.2 kg) did not differ between the groups ($p = 0.1420$).

At the end of the procedure, only three animals (two from G5 and one from G20) needed neuromuscular block reversal. For those animals, the researchers administered atropine (0.02 mg·kg^{-1}, IV), followed by neostigmine (0.02 mg·kg^{-1}, IV).

Among all the urinary system variables evaluated (**Table 1**), only UO showed differences between groups at T8 ($p = 0.001$), in which significant higher values were noted for G20 compared to G5 (**Fig. 1**).

All groups presented hypothermia during surgery, which was more accentuated at T6, T7, and T8, which differed from T0 ($p < 0.05$). At T1, T3, and T7 there was a significant difference

Table 1. Urinary system variables in female dogs undergoing different fluid therapy rates

Variables	Evaluation moment	G5 (n = 8)	G10 (n = 8)	G20 (n = 8)
P/C ratio	T0	0.19 ± 0.16	0.25 ± 0.11	0.56 ± 0.50
	T9	0.26 ± 0.16	0.48 ± 0.57	0.16 ± 0.12
Creatinine (mg/dL)	T0	1.10 ± 0.17	1.08 ± 0.16	1.11 ± 0.26
	T9	0.93 ± 0.20	1.00 ± 0.12	1.02 ± 0.28
Urea (mg/dL)	T0	30.92 ± 9.32	31.19 ± 13.02	27.59 ± 9.20
	T9	37.61 ± 10.39	36.88 ± 10.19	39.20 ± 12.26
Urine specific gravity	T0	1,036^{ab} ± 15	1,042^{a} ± 9	1,025^{b} ± 11
	T9	1,041 ± 8	1,041 ± 9	1,047^{c} ± 18

Values are presented as mean ± SD.
T0, baseline; T8, extubation moment; T9, data collected 24 h after the end of surgery; G5, 5 mL·kg^{-1}·h^{-1}; G10, 10 mL·kg^{-1}·h^{-1}; G20, 20 mL·kg^{-1}·h^{-1}; P/C ratio, protein to creatinine ratio.
^{a,b}Different superscript letters indicate results with significant differences between groups ($p = 0.027$, Tukey's test). ^{c}Difference to T0 ($p = 0.015$, *t*-test).

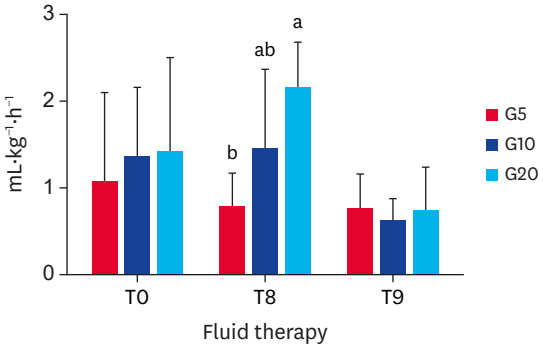

Fig. 1. Mean ± SD of the urine output in female dogs undergoing different fluid therapy rates.
G5, 5 mL·kg^{-1}·h^{-1} (n = 8). G10, 10 mL·kg^{-1}·h^{-1} (n = 8). G20, 20 mL·kg^{-1}·h^{-1} (n = 8).
^{a,b}Different letters indicate results with significant differences between groups ($p = 0.001$, Tukey's test).

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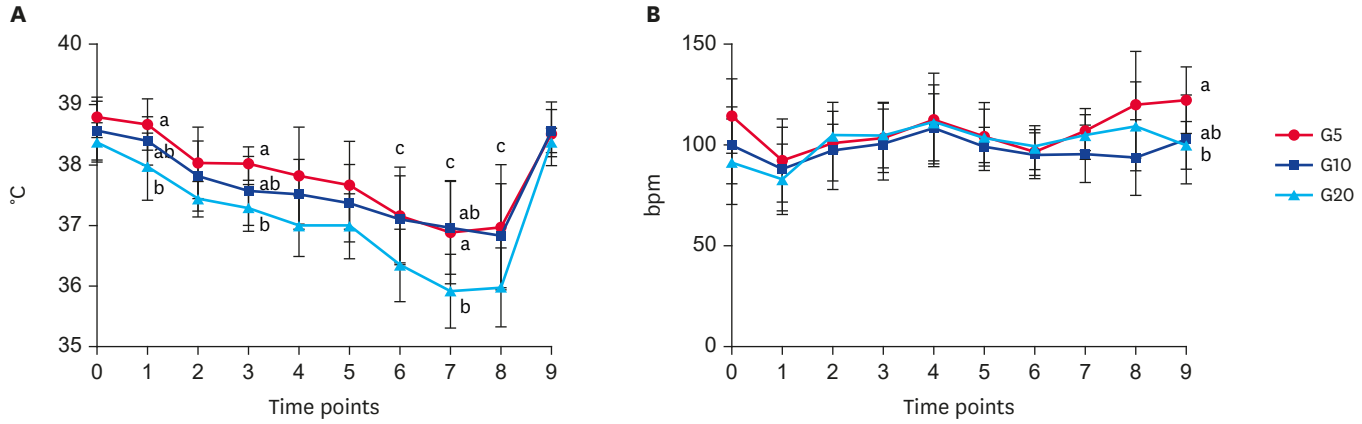

Fig. 2. Mean ± SD of the temperature (A) and heart rate (B) in female dogs undergoing different fluid therapy rates.
G5, 5 mL·kg^{-1}·h^{-1} (n = 8). G10, 10 mL·kg^{-1}·h^{-1} (n = 8). G20, 20 mL·kg^{-1}·h^{-1} (n = 8).
[a,b]Different letters indicate results with significant differences between groups ($p < 0.05$). [c]Difference of groups to T0 ($p < 0.05$, Tukey's test).

between the groups ($p < 0.05$). Dogs in G20 became more hypothermic at the end of the procedure (35.93 ± 0.61°C) ($p = 0.032$). There were no HR variations during the evaluation times, although there was a significant difference between groups in T9 ($p = 0.042$) (**Fig. 2**).

Despite the increase in CVP values after establishing the pneumoperitoneum (T4), this parameter not differ significantly between groups. The increase in CVP was significant in G5 at T4 ($p = 0.039$) and in G20 at T6 ($p = 0.013$), when compared to T2. The lowest values for arterial blood pressure (SAP, DAP, MAP) were recorded after anesthetic induction (T2). In all the groups, the highest arterial blood pressure values from the perioperative period were recorded after administering 12 mmHg into the pneumoperitoneum (T4, which differed from T2; $p < 0.05$) (**Fig. 3**).

The concentration of serum lactate did not differ between the evaluation times within groups, despite its constant increase after anesthetic induction in G5. However, there was a difference between groups at T8. The average values in G5 were significantly higher than the ones in G20 ($p = 0.036$) (**Fig. 4A**). The APP was similar between groups, although the lowest values were identified on G5 at T6 ($p = 0.076$). After the establishment of the pneumoperitoneum, only the values of G20 at T4 ($p = 0.001$) and T6 ($p = 0.034$) differed from the baseline values of this variable registered at T3 (**Fig. 4B**).

The PaO_2 and SaO_2 mean values remained within the physiological range for the species during the whole evaluation time. HCO_3^- did not differ between groups or between evaluation times within groups (**Table 2**).

Regarding pH values, there was no significant difference between the groups. However, the lowest average values were observed in G5. In all groups the pH values lowered during the intraoperative period, differing significantly from the baseline values ($p < 0.05$). However, this occurred earlier and for a longer time in G5. At T8, the average values for G10 ($p = 0.076$) and G20 ($p = 0.081$) did not differ from T0; at T8, six animals from G10 and six animals from G20 presented pH values above 7.30, while for G5, only two animals exhibited similar values. The highest PaCO2 values ($p < 0.05$) were observed for all groups at the intraoperative evaluation times. Respiratory acidosis was evident in animals from all the groups, being more severe after the establishment of pneumoperitoneum (T4) (**Table 2**).

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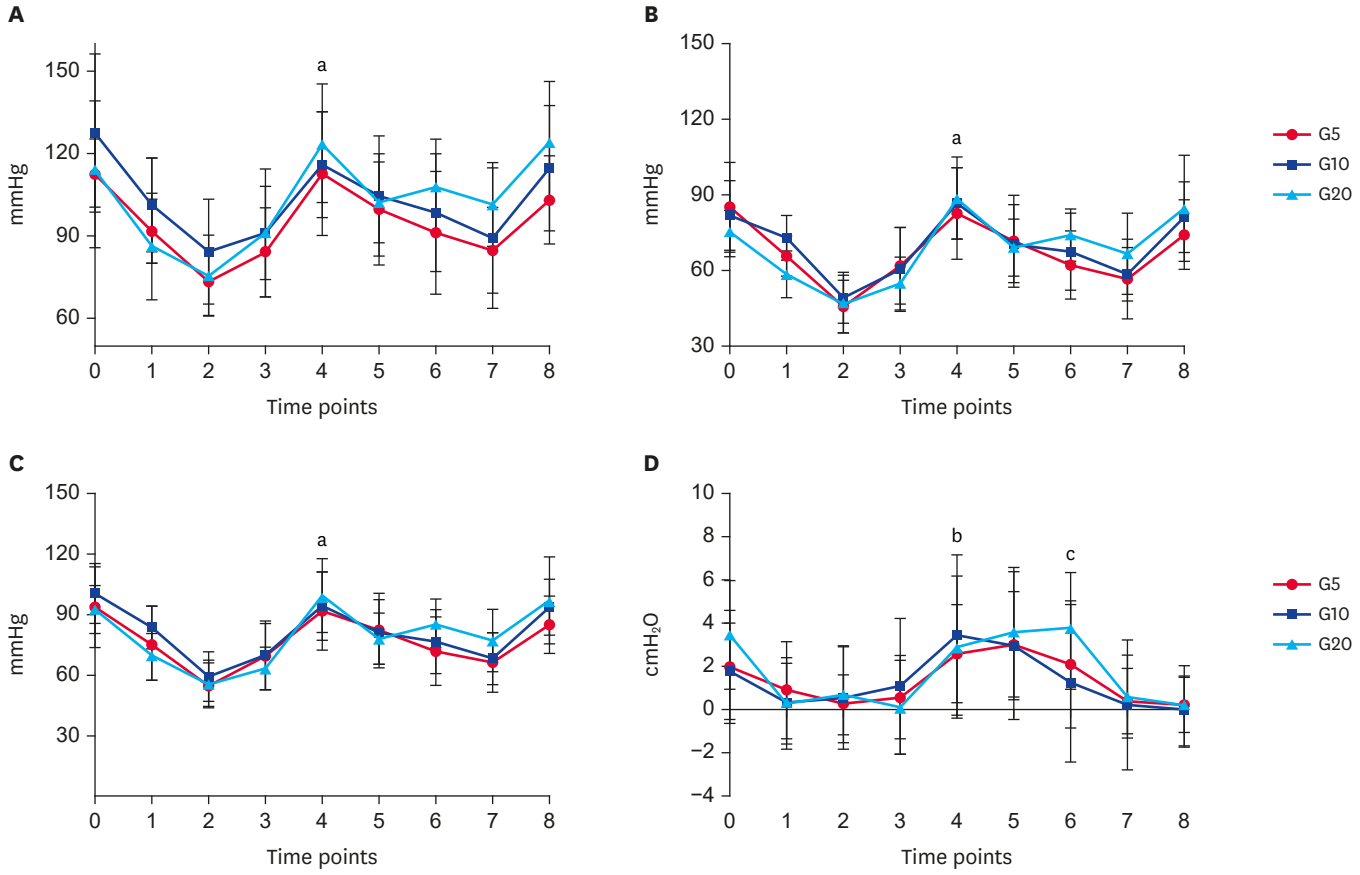

Fig. 3. Mean ± SD of the SAP (A), DAP (B), MAP (C), and CVP (D) in female dogs undergoing different fluid therapy rates.
SAP, systolic arterial blood pressure; DAP, diastolic arterial blood pressure; MAP, mean arterial blood pressure; CVP, central venous pressure; G5, 5 mL·kg^{-1}·h^{-1} (n = 8); G10, 10 mL·kg^{-1}·h^{-1} (n = 8); G20, 20 mL·kg^{-1}·h^{-1} (n = 8).
[a]Difference between T2 and T4 in all groups ($p < 0.05$); [b]Difference between T2 and T4 on G5 ($p = 0.039$); [c]Difference between T2 and T6 on G20 ($p = 0.013$, Tukey's test).

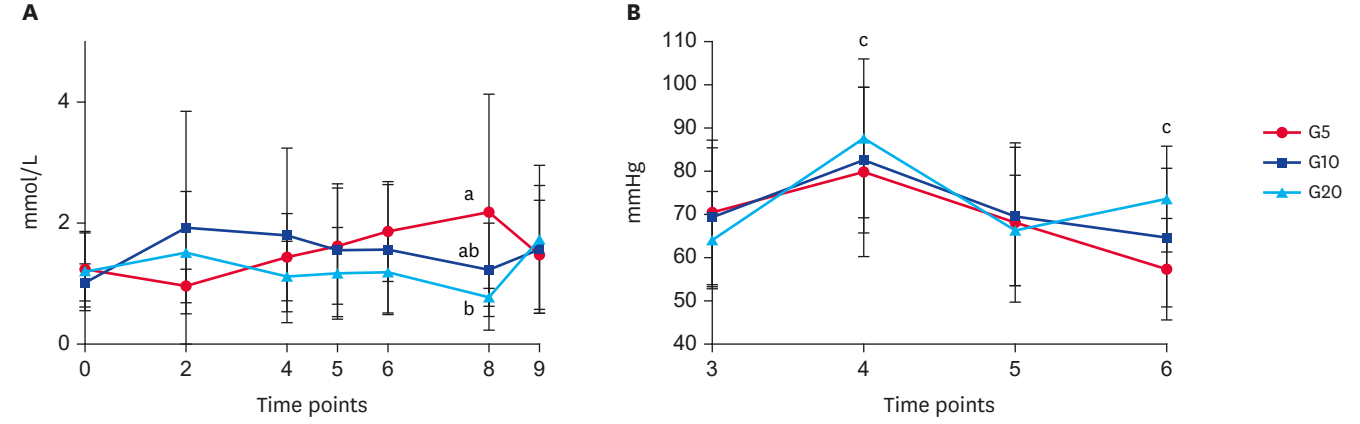

Fig. 4. Mean ± SD of lactate (mmol/L) (A) and abdominal perfusion pressure (B), in female dogs undergoing different fluid therapy rates.
G5, 5 mL·kg^{-1}·h^{-1} (n = 8); G10, 10 mL·kg^{-1}·h^{-1} (n = 8); G20, 20 mL·kg^{-1}·h^{-1} (n = 8).
[a,b]Different letters indicate results with significant differences between groups ($p = 0.036$, Tukey's test); [c]Difference of G20 to baseline (T3) ($p < 0.05$, Tukey's test).

BE values did not vary significantly between the groups. However, in G5 ($p = 0.001$) and G10 ($p < 0.001$) these values varied over time, with the lowest ones being recorded between T5 and T7 (which differed significantly from the baseline data) and exceeded the physiological values for the species. In G20, BE values did not change over time (**Table 2**).

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Table 2. Hemogasometric variables, *f*, and $ETCO_2$ in female dogs undergoing different fluid therapy rates

Variables	Group	T0	T2	T4	T5	T6	T7	T8	T9
Ph	G5	7.40 ± 0.01	7.34 ± 0.02[a]	7.29 ± 0.04[a]	7.27 ± 0.04[a]	7.26 ± 0.04[a]	7.26 ± 0.06[a]	7.28 ± 0.07[a]	7.40 ± 0.07
	G10	7.40 ± 0.02	7.35 ± 0.04	7.31 ± 0.02[a]	7.28 ± 0.04[a]	7.27 ± 0.05[a]	7.29 ± 0.05[a]	7.33 ± 0.04	7.42 ± 0.02
	G20	7.39 ± 0.04	7.35 ± 0.04	7.33 ± 0.04	7.29 ± 0.03[a]	7.26 ± 0.03[a]	7.29 ± 0.04[a]	7.30 ± 0.05	7.40 ± 0.02
PaO_2	G5	103.4 ± 27.58	446.0 ± 33.29[a]	428 ± 41.87[a]	411.5 ± 58.50[a]	382.5 ± 97.10[a]	410.1 ± 69.36[a]	386.1 ± 134.2[a]	83.21 ± 25.25
	G10	94.91 ± 17.35	428.35 ± 58.91[a]	437.70 ± 74.67[a]	402.71 ± 37.05[a]	392.25 ± 51.48[a]	432.69 ± 52.91[a]	294.68 ± 157.53	87.66 ± 11.91
	G20	99.33 ± 7.43	420.31 ± 67.64[a]	405.38 ± 122.96[a]	418.27 ± 56.63[a]	417.51 ± 86.63[a]	416.54 ± 68.51[a]	318.75 ± 170.83	90.68 ± 6.30
$PaCO_2$	G5	33.24 ± 3.10	39.89 ± 3.17[a]	43.55 ± 4.56[a]	45.99 ± 4.44[a]	47.50 ± 4.82[a]	48.64 ± 6.29[a]	47.70 ± 12.23	35.11 ± 5.40
	G10	33.58 ± 2.21	37.58 ± 5.60	41.25 ± 1.89[a]	44.65 ± 5.29[a]	46.21 ± 5.64[a]	44.99 ± 5.87[a]	40.51 ± 6.09	32.91 ± 1.84
	G20	34.56 ± 4.55	36.12 ± 5.62	40.54 ± 4.47	45.20 ± 2.85[a]	49.40 ± 3.59[a]	46.54 ± 3.68[a]	47.27 ± 6.60[a]	34.96 ± 4.72
HCO_3^-	G5	20.40 ± 1.90	21.14 ± 1.42	20.93 ± 0.63	20.71 ± 1.14	20.90 ± 1.07	21.24 ± 1.30	21.64 ± 2.44	21.00 ± 1.38
	G10	20.59 ± 1.27	20.18 ± 1.97	20.49 ± 1.03	20.74 ± 1.24	20.88 ± 0.89	21.26 ± 0.77	21.16 ± 1.32	21.39 ± 1.13
	G20	20.39 ± 1.97	19.79 ± 3.01	21.03 ± 2.24	21.41 ± 2.10	22.13 ± 1.15	21.84 ± 1.64	22.69 ± 1.00	21.23 ± 2.19
SaO_2	G5	96.81 ± 0.77	99.62 ± 0.60	99.69 ± 0.41	99.85 ± 0.08	99.60 ± 0.50	99.72 ± 0.28	99.41 ± 0.89	96.76 ± 1.24
	G10	94.94 ± 5.83	99.76 ± 0.16	99.76 ± 0.10	99.83 ± 0.10	99.81 ± 0.06	99.79 ± 0.16	99.03 ± 1.21	95.64 ± 2.75
	G20	97.12 ± 0.48	99.62 ± 0.49	99.90 ± 0.11	99.87 ± 0.10	99.85 ± 0.09	99.83 ± 0.11	99.01 ± 1.09	92.89 ± 9.36
BE	G5	−3.31 ± 1.54	−4.20 ± 1.32	−5.17 ± 0.99	−5.92 ± 1.13[a]	−5.97 ± 1.06[a]	−5.80 ± 1.61[a]	−4.90 ± 1.43	−2.87 ± 2.35
	G10	−3.19 ± 1.15	−4.91 ± 1.62	−5.33 ± 1.20[a]	−5.56 ± 1.28[a]	−5.75 ± 1.17[a]	−5.03 ± 1.10[a]	−4.21 ± 0.82	−2.15 ± 1.07
	G20	−3.75 ± 1.75	−5.11 ± 2.86	−4.49 ± 2.27	−4.96 ± 2.23	−4.83 ± 1.43	−4.60 ± 1.97	−3.65 ± 0.98	−2.74 ± 1.53
f	G5	47.63 ± 47.99	11.88 ± 1.25	12.75 ± 2.96	14.00 ± 3.07	17.63 ± 4.17[b]	18.25 ± 3.37[b]	18.43 ± 9.88	29.00 ± 8.48[b]
	G10	59.00 ± 52.01	11.13 ± 2.29	10.13 ± 3.94	12.50 ± 4.57	16.13 ± 3.44[b]	15.38 ± 4.27	17.63 ± 6.12	59.00 ± 34.85
	G20	51.50 ± 45.98	10.50 ± 2.56	11.88 ± 4.55	12.13 ± 3.31	15.71 ± 1.98[b]	14.50 ± 3.38	22.86 ± 18.31	55.00 ± 32.97
$ETCO_2$	G5	-	38.25 ± 3.45	40.38 ± 4.31	41.25 ± 3.69	41.88 ± 2.59	42.25 ± 3.10	-	-
	G10	-	36.00 ± 4.54	37.63 ± 4.69	40.25 ± 3.61	39.63 ± 3.54	39.13 ± 3.64	-	-
	G20	-	35.75 ± 2.71	36.13 ± 1.46	40.63 ± 4.00	41.13 ± 3.44	39.13 ± 2.59	-	-

Values are presented as mean ± SD.
f, respiratory rate; $ETCO_2$, end-tidal partial pressure of carbon dioxide; G5, 5 $mL \cdot kg^{-1} \cdot h^{-1}$ (n = 8). G10, 10 $mL \cdot kg^{-1} \cdot h^{-1}$ (n = 8). G20, 20 $mL \cdot kg^{-1} \cdot h^{-1}$ (n = 8); PaO_2, arterial oxygen partial pressure; $PaCO_2$, arterial carbon dioxide partial pressure; HCO_3^-, sodium bicarbonate; SaO_2, arterial oxygen saturation; BE, base excess.
[a]Difference to T0. [b]Difference to T2. Tukey's test.

The total CO_2 values (in liters) used to establish the pneumoperitoneum did not differ between the groups ($p = 0.627$), being 26.67 ± 2.93 for G5, 26.14 ± 5.08 for G10, and 24.44 ± 5.40 for G20.

Among the electrolytes measured in the present study (**Fig. 5A-C**), only potassium showed differences between the evaluation times in G10 ($p = 0.005$) and G20 ($p = 0.028$), with no differences being observed between the groups. The lowest values of this electrolyte were recorded both in the G10 and G20 groups (**Fig. 5A-C**) from T2 to T8, including values below the reference values for the species, found in G20.

The AG values (**Fig. 5D**) remained within the physiological range for the species in all the groups. However, during all intraoperative timepoints, values in G20 were lower than those in G5 and G10. At T6 ($p = 0.048$) and T7 ($p = 0.017$) such difference was evident.

DISCUSSION

Several factors can influence cardiorespiratory variables and arterial blood gas analysis, including general anesthetics and depth of anesthesia [16]. In this study, however, there was no difference between the groups regarding ETiso, *f*, $ETCO_2$, surgical time, extubation time, and fluid therapy time.

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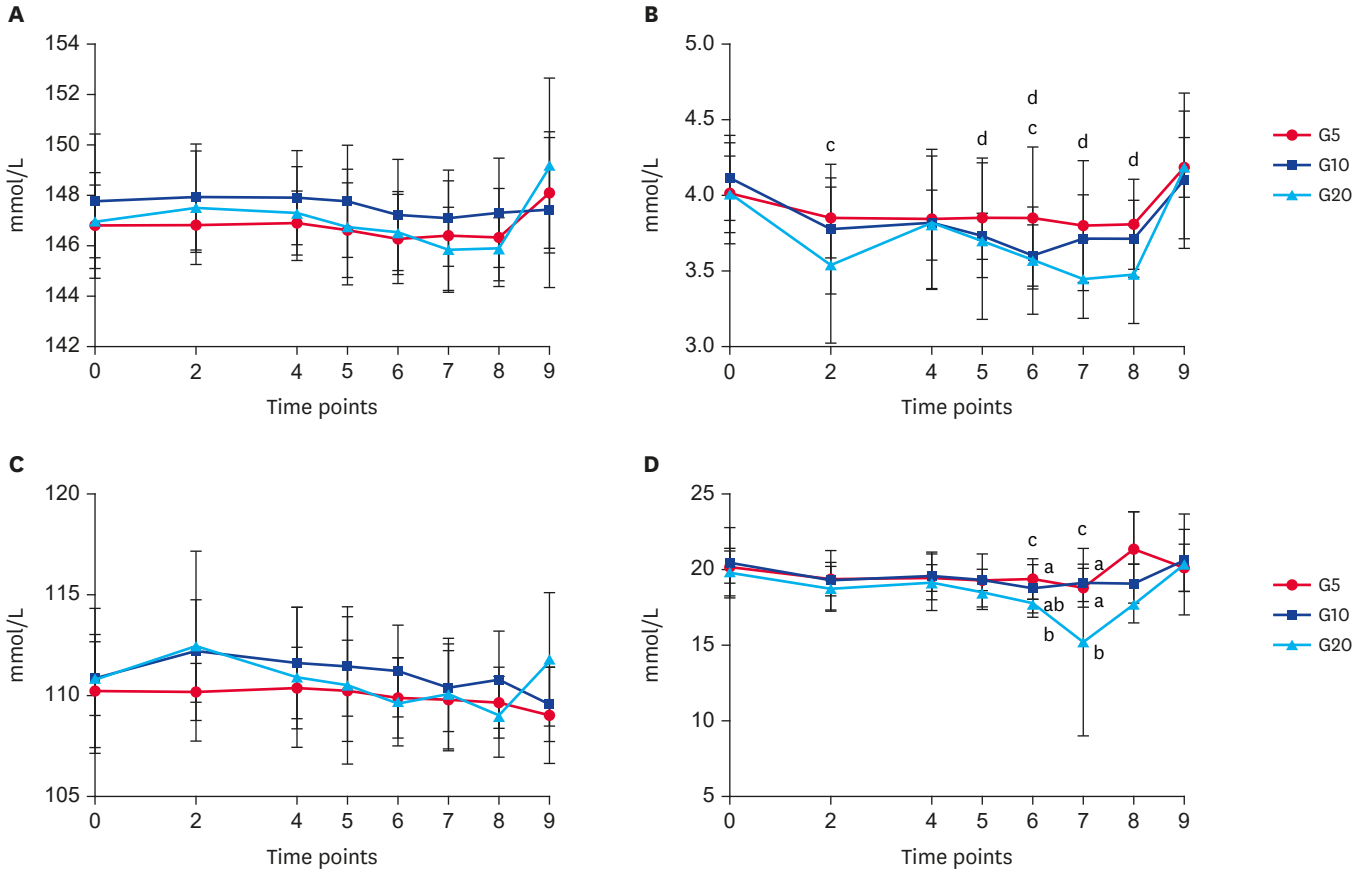

Fig. 5. Mean ± SD of sodium (A), potassium (B), chloride (C), and AG (D) in female dogs undergoing different fluid therapy rates.
G5, 5 mL·kg^{-1}·h^{-1} (n = 8). G10, 10 mL·kg^{-1}·h^{-1} (n = 8). G20, 20 mL·kg^{-1}·h^{-1} (n = 8).
[a,b]Different letters indicate results with significant differences between groups (Tukey's test). [c]Difference of G20 to T0 ($p < 0.05$). [d]Difference of G10 to T0 ($p < 0.05$).

Due to the fact that the study was conducted with routine animals, the recommended IAP for the procedure was established (12 mmHg) and did not vary according to the weight of the animal. The CO_2 volume used was adjusted by the insufflation equipment for each particular abdominal space. Both the total CO_2 volume (L) used to perform the surgeries and the weight of the animals did not vary significantly between groups.

This type of surgery usually results in tachycardia and hypertension after the administration of medical CO_2 into the pneumoperitoneum, either because this gas promotes sympathetic stimulation [17] or due to the increase in IAP [3,17]. In the present study, only arterial blood pressure increased immediately following the abdominal cavity insufflation (T4). However, after 5 min (T5) the values did not vary significantly from T3 or T0.

Although CVP did not present any significant difference between the groups, the values increased when the animals were under pneumoperitoneum effect and received mechanical ventilation. Both factors can contribute to this elevation, which is consistent with other studies [18,19]. However, this study found that the hemodynamic variables were affected by the surgical procedure, while the different fluid therapy rates had no effect upon them.

APP has been proposed as an accurate predictor of visceral organ perfusion in humans [20]. Improving intra-abdominal perfusion in patients with intra-abdominal hypertension (IAH) is

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extremely important in terms of morbidity and mortality [21]. APP values and their consequences have only been documented in felines, but not in canines [22]. Further, human studies demonstrate that a decrease in APP is related to a worse prognosis in individuals with IAH, with cut-off values of 60 mmHg [23,24] and 53 mmHg [25], for adults and children, respectively.

Although in this study there was no significant differences between the groups in the assessment of APP, only G5 showed values below 60 mmHg, the cut-off point used for humans. The real implications of these findings are not known due to the scarce number of studies about this parameter in animals. The authors encourage further studies to clarify the benefits of this evaluation in the perioperative environment of videosurgeries. This is the first study on APP in canines and if it can be used as an indicator of tissue perfusion during the perioperative period, it would be a low cost and easy to implement tool in the routine procedures of videosurgery.

After anesthetic induction, G5 was the only group that showed a progressive increase in the lactate values throughout the intraoperative period—statistical significant difference between groups was evidenced at T8. The increase in serum lactate at the end of the procedure on animals of G5 might be the result of the restrictive fluid therapy in this group, which could have increased the tissue hypoperfusion caused by the pneumoperitoneum [4]. This becomes relevant because in a surgical procedure, where anesthesia lowers oxygen consumption [26], the increase in lactate is not expected.

Recently, the increasing intraoperative serum lactate levels have been observed exclusively in patients who developed postoperative acute kidney injury (AKI), demonstrating that intraoperative serum lactate may be an important and effective biomarker to prevent and diagnose postoperative AKI in the studied population [27]. This supports the hypothesis that the restrictive fluid therapy rate for video-assisted procedures may present no benefit to the animals.

The fact that pneumoperitoneum may cause renal changes such as reduced tissue perfusion, reduction of glomerular filtration rate, and decreased UO is due to the increased IAP [28]. Variables such as UO were measured during surgery, remaining within the normal range for the species only in animals of G10. Animals from G5 presented perioperative oliguria when compared to the other groups, which can be related to the reduction of the glomerular filtration rate. The mean values of G20 remained above the reference values for the species, suggesting hyperhydration with consequent kidney overload.

Oliguria is well documented in animals and humans submitted to high IAP (pneumoperitoneum) [29,30], and to inhalation anesthesia by increasing vasopressin release [31], which may impair the assessment of UO. In this study, the depth of anesthesia was similar between the groups and all were submitted to 12 mmHg of pneumoperitoneum. Different fluid therapy rates affected the UO and, therefore, should be regarded as attempts to minimize perioperative oliguria and to avoid overloading the kidneys up to the point of causing polyuria. When evaluating the effects of anesthesia, surgery, and intravenous administration of fluids on plasma on the antidiuretic hormone concentrations in healthy dogs, Hauptman et al. [31] concluded that the administration of fluids was an important factor for maintaining urine production during the intraoperative periods. Urine specific gravity values did not show significant differences between groups after fluid therapy at T9, although they were different at T0. Such difference is not physiologically relevant since all the values were within the physiological range for the species [32] and because the urine specific gravity may be affected by water intake, food, and activity level [33].

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Despite the lack of scientific evidence, restrictive rates of fluid therapy are currently recommended [6] in order to minimize the risks related to hypervolemia [1]. Several parameters can be related to fluid overload, such as an increase in UO, as previously discussed. AG is commonly used to assist in the diagnosis of metabolic acidosis whenever its elevation is observed, while AG values lower than the reference interval in animals with hypoproteinemia [34]. Despite the fact that all the observed AG values were within the physiological range [35] throughout all the intraoperative times, animals from G20 presented lower values than the other groups (at T6 and T7, such difference was particularly evident, $p < 0.05$), which can be explained by the dilution of plasma proteins, causing a reduction of the negative protein charge [34] due to the administration of a liberal fluid therapy to this group.

The mean potassium values resulted in hypokalemia only in G20, considering 3.7–5.8 mEq/L as reference values [36]. The lower potassium values observed in G20 can be related to the higher rate of fluid administration to these animals, which resulted in an increase on the electrolyte excretion due to lower resorption at the distal and proximal contorted tubules [37].

In a study conducted in an academic teaching setting, the clip area percentage was associated with perioperative unexpected hypothermia, while surgical duration and total anesthesia time was not associated with the risk of hypothermia [38]. In the present study, clipping the area was standardized for video-assisted OH and, in addition, there was no significant difference between the groups regarding the time of anesthesia. Even though all animals were positioned over an active heating blanket throughout the anesthetic period, all of them developed hypothermia during surgery. This effect was more severe in animals from G20. That was expected, because according to Jacob et al. [7], the decrease in body temperature is one of the risks associated with great amounts of fluids. In order to minimize this effect, avoid hemodynamic and ventilatory changes, and alterations in oxygenation [39], other active heating methods could be implemented, such as the administration of warmed fluids [40].

Despite the adoption of the ventilatory measures as indicated in the literature for the animals submitted to video-assisted procedures (such as mechanical ventilation [41]) and changes in the respiratory rate to adjust $ETCO_2$ values, respiratory acidosis was observed in all the groups during the intraoperative period and increased after the administration of the pneumoperitoneum (T4). This can be attributed to the peritoneal absorption of CO_2, increasing arterial blood levels and reducing the pH [17].

The values of HCO_3^- did not differ between the groups or between the evaluation times within groups. However, there was a slight increase in its values after the establishment of the pneumoperitoneum, suggesting metabolic compensation due to acute respiratory acidosis. Further, Morais and DiBartola [42] noted that an increase of 0.15 mEq/L on (HCO_3^-) can be expected for each increase of 1 mmHg in PCO_2 in dogs.

The absence of significant differences in the total volume of CO_2 used to sustain the pneumoperitoneum of 12 mmHg should be emphasized, because acidosis in animals submitted to video-assisted procedures is related to peritoneal CO_2 absorption [17]. Therefore, the occurrence of a more accentuated acidosis in animals in G5 may be linked to the fact that they received a restrictive rate of lactated Ringer's solution. The alkalizing properties of this solution [43] may have attenuated the condition of acidosis in animals that received a greater volume of this fluid (G10 and G20).

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Despite the current 5 mL·kg^{-1}·h^{-1} rate of fluid therapy usually recommended for dogs submitted to low-risk procedures (based only on the professional experience of colleagues) [6], the results herein presented support the hypothesis that such rate may not be recommended for dogs submitted to video-assisted OH. The potential effects include intraoperative oliguria, progressive increase in serum lactate, and lower values of BE, which should also be considered for tissue perfusion assessment. The animals from G5 presented acidosis earlier and for a longer time and the lowest values of APP were presented at the end of the establishment of the pneumoperitoneum. Although we do not know the real clinical impact of this variable due to the few number of works about it, in studies of humans with IAH, the lowest APP values are related to worse prognoses. Moreover, the liberal fluid therapy, advocated by some authors [9], resulted in the present study in polyuria, reduced AG, hypokalemia, and more severe hypothermia, suggesting fluid overload.

Perioperative fluid therapy is still poorly studied in Veterinary Medicine, still presenting great knowledge gaps. In the literature consulted, this is the first study that evaluates the different rates of administration of lactated Ringer's solution for an increasingly used surgical technique that presents important particularities, such as IAH promoted by pneumoperitoneum. The data obtained from this study contributes to the improvement of perioperative fluid therapy in veterinary videosurgery by minimizing the risks inherent to the surgical procedure, such as the hypoperfusion of abdominal organs.

Shin et al. [12], in their study of 92,094 people, showed the importance of the impact that intraoperative fluid therapy has on the postoperative outcomes of patients. The authors distributed the individuals among five fluid administration ranges: restrictive, moderately restrictive, moderate, moderately liberal, and liberal. They found that the mortality rate and AKI were higher in individuals who received restrictive and liberal fluid therapy. For most patients, a moderately restrictive approach to fluid management during surgery can promote the best postoperative results [12]. In veterinary medicine, we do not have an analysis of this magnitude on the impact of different rates of perioperative fluid therapy, nor a consensus on what can be considered a restrictive, moderately restrictive, moderate, moderately liberal, or liberal fluid therapy. Accordingly, our study provides initial contributions about this issue regarding laparoscopic procedures with small animals.

Some limitations of our study were inherent to clinical trials, such as the short period of exposure of the animals to the pneumoperitoneum during an elective video-assisted OH, which might explain the slight differences observed between the groups. The complexity of assessing tissue perfusion in animals submitted to routine hospital procedures was another limiting factor.

The available methods for evaluating microcirculation are very limited. Nevertheless, there is evidence that accurate assessment and monitoring of tissue perfusion using parameters of global O_2 metabolism is essential for the selection of the most appropriate therapeutic strategy [44]. Among the biochemical parameters of global O_2 metabolism used as clinical markers of different aspects of the microcirculation and tissue perfusion status, such as mixed venous oxygen saturation (S_vO_2), lactate, venous–arterial carbon dioxide difference (PCO_2 gap) and PCO_2 gap/arterial–venous difference in oxygen (Ca-vO_2) [44], only lactate was assessed in our study.

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Based on the results of our study it was not possible to determine the clinical importance of different LRS administration rates for healthy dogs undergoing videosurgery. However, dogs with pre-existing kidney disease or animals with predisposing factors for its development can benefit from a conventional fluid therapy rate (10 $mL \cdot kg^{-1} \cdot h^{-1}$). Therefore, this rate should be tested in a large prospective study with animals under such conditions.

According to the results presented and discussed in this work, the administration of lactated Ringer's solution at a rate of 10 $mL \cdot kg^{-1} \cdot h^{-1}$ seems to be more beneficial in elective laparoscopic procedures than at 5 or 20 $mL \cdot kg^{-1} \cdot h^{-1}$ rates of infusion.

SUPPLEMENTARY MATERIALS

Supplementary Table 1

Variables and time points

Click here to view

Supplementary Fig. 1

Variables and time points.

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