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Research paper

Comparison of liberal and goal-directed fluid therapy after small intestinal surgery for strangulating lesions in horses

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Abstract

Background: There are few guidelines for the appropriate mode of fluid administration during and after colic surgery, and is challenging to to reach the right balance while avoiding overhydration. This study aimed to compare goal-directed fluid therapy (GDFT) and 'liberal' (LFR) fluid regimens in horses undergoing small intestinal surgery.

Methods: Eighteen horses subjected to small intestinal surgery were matched according to the surgical lesion, type of anastomosis, length of resection, and duration of clinical signs. Horses in the LFR group were administered intravenous (IV) fluids for at least 24 h. In the GDFT group, IV fluids were administered only when considered necessary based on clinical parameters. Postoperative reflux (POR), packed cell volume, total protein, heart rate, venous lactate level, complications, and long-term survival rates were compared.

Results: Three horses in the LFR and one in the GDFT group developed POR. Horses in the GDFT group had a shorter time interval to first oral water intake and shorter hospitalisation time. Postoperative complication rates and survival were not different between groups.

Conclusion: Further studies are necessary to set guidelines for the evaluation of hydration status and to plan postoperative fluid administration; however, GDFT may be a valid alternative to liberal fluid therapy after colic surgery.

Keywords: colic, fluid therapy, postoperative complications

Introduction

Intravenous fluid administration (IFA) in the postoperative period is an important component of postoperative care following intestinal surgery in human and veterinary patients; however, both delivery volumes and rates selected in veterinary medicine tend to be arbitrary, with most published guidelines lacking scientific support.[1] The conventional postoperative IFA scheme for horses recovering from colic surgery is based on a 'maintenance rate', which is calculated based on the patient's weight and then integrated with fluid losses.

Maintenance rates have been determined in fed horses—a condition completely different from horses recovering from colic surgery. Recently Freeman et al.[2] demonstrated that healthy horses on a restrictive diet had water needs far below those recommended for horses on normal feed, highlighting the need for modulating IFA in the postoperative period. Although postoperative IFA is not based on the maintenance rate alone, one should consider that the 'maintenance rate', as used so far and added to replacement rates, may lead to overhydration.

IFA volumes far exceeding the patient's actual needs appear to be common practice in the postoperative management of colic in horses; moreover, some evidence suggests that overhydration could reduce colloid osmotic pressure to levels related to decreased survival;[3] moreover, a low intraoperative packed cell volume (PCV) was predictive of anaesthesia recovery failure and the need for gastric decompression after surgery.[4] In humans, an inappropriate fluid balance can aggravate tissue inflammation, compromise wound healing, promote anastomotic leakage, and increase the incidence of ileus.[5,6,7]

Both Freeman[2,8] and Merritt and Blikslager[9] advocated the need to re-think IFA in horses after colic surgery—especially in cases with a high risk of developing postoperative reflux (POR). In a recent study, Hoaglund et al.[10] tried to correlate the presence of POR with the volume of IFA in a large and heterogeneous population of colic cases, and they concluded that IFA should be modulated based on the horses' need based on biochemical data.

Further, fluid costs are high and can substantially add to costs of treatment—which may reduce options for owners where finances are limited.

The current challenge in equine colic surgery now is to determine the right volume of fluid to be given to avoid both fluid overload and hypovolemia/hypoperfusion.

In humans, to address these challenges, goal-directed fluid therapy (GDFT) has been proposed as an approach to tailor IFA according to the individual needs of patients undergoing major surgery.[11] Several studies in people suggest that GDFT is useful to improve postoperative outcomes and to decrease postoperative morbidity and both the duration and cost of hospitalisation.[12-14]

We hypothesised that GDFT could be effective in the postoperative management of equine colic cases. This study aimed to: (I) evaluate the differences between two fluid protocols in terms of short- and long-term complications and follow-up, and (II) evaluate the validity of commonly used haematological and clinical parameters used to assess hydration status in colic horses.

Materials and methods

This was a retrospective, single-centre, study comparing two different groups of horses that received different fluid therapy regimens, conducted between 2015 and 2019 as a 'before-and-after treatment' evaluation.

Animals

Medical records of horses admitted to our university between January 2015 and May 2019 that recovered from colic surgery, had a definitive diagnosis of strangulating small intestinal disease, and survived to discharge were retrieved. Foals younger than 1 year and miniature horses were excluded. For each case admitted between January 2015 and December 2016, a matched case admitted between January 2017 and April 2019 was selected. Matching was accomplished based on the surgical pathology, type of anastomosis, length of resection, and duration of clinical signs. Surgical pathology was determined by the definitive diagnosis made at surgery. The same assumption was considered both for determining the type of anastomosis and the length of resection.

The parameter 'duration of clinical signs' was defined as the interval between hospital admission and the 'last time seen normal' by the owner/stable keeper. Since exact matching according to clinical sign duration was impossible— because clinical signs were variable, and the measurements were not accurate to the hour—we introduced classes for their duration (<6 h, 6–12 h, 12–18 h, 18–24 h, >24) and followed the same approach for the length of resection (=0, ≤2 m, >2 m).

Selected horses were assigned either to the liberal (LFR) or GDFT regimen group. Between January 2015 and December 2016, nine horses were enrolled in the liberal fluid regimen group, while between January 2017 and May 2019, nine matched horses were assigned to the GDFT group. All horses were operated on by the same surgeon (MG).

Fluid regimens

Either before or during anaesthesia, both groups received 'resuscitation' fluid regimens of 20–80 mL/kg of crystalloids (lactated Ringer's solution starting at 20 mL/kg, which was then adjusted after reassessment) and eventually hypertonic saline and starch-based colloids at the discretion of the anaesthetist and as determined by cardiovascular and clinical status, PCV, total protein (TP) level, and venous or arterial lactate level. After surgery, the LFR group were administered intravenous (IV) fluids at a maintenance rate of 2 mL/kg/h (plus fluid losses) for at least 24 h post-recovery from anaesthesia. Patients in the GDFT group were not routinely administered any IV fluid after recovery from anaesthesia. Fluid therapy was either terminated, adjusted (both groups), or initiated (GDFT group) based on clinical status, an increase in heart rate (HR), PCV, TP levels, and venous lactate levels, or the presence of POR. These parameters—and the total administered IV fluid and water intake—were measured upon arrival, immediately after surgery, and every 4 h. Venous lactate level was excluded because it was measured initially every 2 h.

Jejunojejunal anastomoses were performed in an end-to-end fashion with a continuous appositional pattern. Jejunocaecal anastomoses were mostly performed in a handsewn double-layer fashion, while in two cases (one per group), they were performed with an 80-mm gastrointestinal anastomosis (GIA) stapler.[a] The fluid content of the whole small intestine was emptied into a bucket before resection; then, a pelvic flexure enterotomy was performed in all cases, emptying the large colon's contents. The abdominal wall was sutured with a simple continuous pattern with two strands of USP 2 Lactomer 9-1 loop (Polysorb). [b] The skin was closed with a simple continuous pattern with USP 1 nylon (Monosof). [c]

In both groups, oral fluid intake was encouraged as much as possible in the postoperative period by providing water soon after surgery; similarly, early feeding within 8 h after recovery was also established because it is part of our hospital's Fast Track Recovery Pathway program. Other treatments were limited to preoperative gentamicin sulphate (Aagent[d], 6.6 mg/kg IV), benzylpenicillin procaine (Prontocill[e], 12.000 IU/kg intramuscular), both pre- and postoperative flunixin meglumine administration (Meglufen[f] 1.1 mg/kg IV bid), and calcium gluconate (CapH[g] at label dose).

To assess the homogeneity of groups, age, weight at arrival, duration of clinical signs, definitive diagnosis, surgical time, and the length of intestine resected were reported and compared, in addition to the preoperative haematoclinical parameters (PCV, TP level, and HR), preoperative reflux quantity, and pre- and intraoperative fluid administration. Short-term complications were defined as the diagnosis of incisional infections (any wound discharge other than serosanguineous discharge), postoperative colic, or POR, which was defined as any net retrieval of fluids at nasogastric intubation, which was performed only if clinical signs (increased HR, pain, increase in PCV/TP) were present. To adjust for horse size, we expressed the litres of fluid retrieved in relation to horse weight (litres of reflux/100 kg body weight) after surgery. Further, we considered the duration of POR between the first nasogastric intubation with the retrieval of reflux and the last attempt in which fluid was retrieved. The duration of hospitalisation was counted to the postoperative day on which the horse was considered ready for discharge, thus avoiding biases introduced by the owners' decisions to collect their horses after a formal discharge recommendation.

Details pertaining to the postoperative fluid regimen (both pre- and intraoperative fluids, postoperative fluid administration, days on IV fluids, and oral water intake) were recorded and compared between groups. To define effects and adjust fluid therapy, the postoperative values of haematological and clinical parameters (PCV, TP level, HR, and venous lactate level) were recorded and compared between groups. An analysis was performed on a blood sample, collected from an IV catheter, discarding at least 15 mL of blood drawn out of the catheter each time before collecting the sample for analysis.[15]

Both long-term survival (>12 months) and the incidence of complications (postoperative colic, incisional infection, and laminitis) were determined by telephone follow-up with the owner.

Statistical methods

Both the study power and sample size were calculated with a custom-made excel calculator, setting the alpha level at 0.05 and 90% power using the mean IV fluid quantity in the first 24 h postoperatively; we assumed that horses in the GDFT group were administered half of the quantity of fluids (12 L/day) than a horse in the LFR group (24 L/day for a 500-kg horse).

Data normality was assessed using the Shapiro-Wilk test. For normally distributed variables, an unpaired *t*-test with Welch correction was used to compare the data, reporting the results as means +/- standard deviations. For variables that did not show a normal distribution, the Mann-Whitney test was used, and the results were reported as medians (ranges). A Fischer's exact test was used to highlight differences in long term survival between groups. Significance was considered for P values less than 0.05. Statistical analyses were performed using commercial software (Prism 8.0, GraphPad, San Diego, California, USA).

Results

Our sample size estimation suggested that eight subjects per group would be optimal. Data on signalment, history, and surgery are reported in Table 1; no intergroup differences were noted for any of these variables. Table 2 reports the results for preoperative haematological and clinical parameters; no intergroup differences were noted any of these parameters. Moreover, no intergroup differences were noted in the administered amounts of pre- and intraoperative fluids, as described in Figure 1. The amounts of preoperative reflux are presented in Figure 2.

Complications before discharge

Regarding short-term postoperative complications, POR developed in one horse alone in the GDFT group and three in the LFR group. The quantity and duration of POR did not differ between groups, as shown in Figure 3. Incisional drainage was reported in one horse alone per group; postoperative colic was reported in one horse in the GDFT group. The groups showed a significant difference in the duration of hospitalisation because the GDFT group presented 20% reduced time, corresponding to approximately 2 days. (Table 1).

Fluid administration

Postoperative fluid administration data are presented in Figure 4. Both the number of IV fluids (Fig. 4A) and the duration (Fig. 4B) of IV fluid administration were significantly different between groups when considering the whole sample. The time between surgery and first-time interval to voluntary water consumption (42.7±19 h for the GDFT group and 57.4±37.5 h for the LFR group, p=0.0457; Fig. 5A) and the quantity of water consumed in the first 24 h (20.5±16.6 ml/kg/day for the GDFT group and 7±6.2 ml/kg/day for the LFR group, p=0.031, Fig. 5B), were significantly different between groups. Subsequently, the intergroup differences were not significant and apparently normalised between days 4 and 6 postoperatively (Fig. 5B).

Clinical parameters

Figure 6A presents the data for PCV, before and after surgery, in the liberal and GDFT groups. The trend of the lines is similar, and the statistical analyses did not highlight any intergroup differences. The variations in the TP level in horses, before and after surgery, are represented in Figure 6B. Both groups showed similar trends with no statistically significant differences. For HR, some differences were highlighted in the postoperative period; the results are shown in Figure 6C. Measurements of lactate level in the venous blood were performed until 72 h after surgery. Both groups showed an initial increase in the lactate level during surgery, followed by a rapid decrease. The behaviour of the groups was similar (Figure 6D), with significant differences being noted only in the immediate postoperative period.

Long-term follow-up data for a minimum of 12 months (range, 12–60 months) were obtained for all enrolled horses. Overall long-term survival (>12 months) was 83.3% with no intergroup difference (88.9 % in the GDFT group; 77.8% in the liberal group; p=1). In the GDFT group, one horse was euthanised due to a colic episode at 13 months. No other episodes were reported for this horse in the intervening period. In the LFR group, one horse was euthanised at 3 postoperative weeks due to a colic episode. Another horse was euthanised due to a colic episode at 8 postoperative months. All other horses showed no reported complications that could be related to the first colic surgery.

Discussion

This study demonstrated that GDFT implementation was possible and did not result in more complications than a standard fluid therapy approach in horses that underwent small intestinal surgery for treatment of strangulating lesions at our institution.

According to Archer[16] and Freeman,[17] equine surgeons should strive to reduce the cost of colic surgery through a more selective approach to drug usage and a greater emphasis on preventing complications[8] to allow more horses to have the chance of undergoing life-saving emergency surgery. This approach could be modelled on the concept of ‘fast-track surgery’, or ‘enhanced recovery after surgery’, applied to human gastrointestinal patients.[8] This study also used other enhanced recovery protocol components, such as early access to water, early enteral feeding, routine emptying of the large colon via pelvic flexure enterotomy, exclusion of routine nasogastric intubation, use of short incisions (when indicated or possible), early ambulation, and strict adherence to the selected fluid regimen.[18-20] Together with reduced IFA, all these procedures may ultimately lead to a reduction in costs for colic surgery, that may, therefore, allow more owners to afford it.

To the best of our knowledge, only one study has attempted to relate IV fluid administration to POR; Hoaglund et al.[10] reported no differences in fluid administration in two groups of horses that underwent colic surgery and developed (cases) or did not developed (controls) POR. However, it is difficult to compare our findings with the findings of that study, due to differences in study design, populations (all colic cases vs small intestinal strangulation cases), and postoperative management. Moreover, they reported that a large proportion of the cases that developed POR involved large intestinal pathologies, which was uncommon in other studies and may indicate other factors related to the horse population or hospital management. The cumulative incidence of POR in our study is similar to those reported in other studies[21], although the percentage in the GDFT group is lower than that in the LFR group. While one could speculate that this difference was attributable to the IV fluid regimen, it also could be due to a 'learning effect' developed during the years covered by the study. In fact, Freeman[21] proposed that technical errors in the anastomotic technique or mechanical causes of anastomotic obstruction were likely causes in most cases of POR, and our results probably support this statement. The duration of POR in these horses was limited to a single retrieval of reflux, further excluding other causes of POR, such as POI, and supporting the statement that surgical factors may contribute to POR more than other factors.[8,21] Excluding the two horses for which a possible explanation of POR has been provided above, the incidence of true POI in our study was 10%, in accordance with the findings reported by Freeman et al.[22] All horses that developed POR in our study had some degree of gastric impaction, revealed by direct palpation at surgery, as reported by others concurrently to other forms of colic.[23] Thus, in addition to the anastomotic technique and intestinal oedema, gastric contents could move from the stomach and contribute to anastomotic impaction in the postoperative period.

Nevertheless food intake should be encouraged in the postoperative period to stimulate gut motility and, in selected cases, to prevent hypertriglyceridemia, eliminate the need for parenteral nutrition.[24-25] and to promote water intake. In fact, Freeman et al.[2] observed that unfed horses drink significantly less than fed horses. This is in accordance with our findings and, in our opinion, contraindicated waiting for the horse to drink water before allowing food intake, as reported by some authors. Actually, the opposite approach may be preferable. In our study, horses that were not

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administered postoperative IV fluids were able to maintain the hydration status achieved by intraoperative fluid therapy for days until sufficient quantities of forage had been ingested. These horses ate before drinking, supporting the statement made by Freeman et al[2] on healthy horses, and suggesting that horses recovering from colic surgery may be overhydrated.

In our study, there was some evidence of overhydration, as demonstrated by the initial decrease of the TP level in both groups, both in the intraoperative and immediate postoperative period followed by a rise in the following days (Fig. 6B). Although an increase in TP level in the postoperative period can also be due to an increase in immunoglobulin or fibrinogen, this finding highlights the importance of modulating pre- and intra-operative fluid administration. We used PCV, TP levels, HR, and lactate levels to guide pre-, intra-, and postoperative fluid administration and to evaluate pre- and postoperative hydration status. High PCV, TP levels, and HR at admission have also been considered as negative prognostic indicators.[8] These parameters widely vary both between and within the horses at different time points, thus inaccurately reflecting hydration status; however, their trend can serve as a rough indicator. The analysis of a larger population of colic cases in our hospital showed that these four values' ratio, both at admission and the end of the surgery, was more likely to be an indicator of outcome than the values at admission alone (Gandini M, unpublished data); further investigations in this area are needed to confirm this.

Lactate levels measured serially over the first several days of hospitalisation appear to provide prognostic information in human critical care medicine and may have a use in equine patients.[26] In line with the findings reported by Edner,[27] we found an increase in the venous blood lactate level after fluid resuscitation, potentially due to a wash-out effect from the tissues. Truly, we found an increase in blood lactate levels during surgery and a decrease uncorrelated to the fluid therapy regimen in the following hours in both groups. Venous blood lactate levels are a useful indicator of perfusion at the tissue level; however, our study's results were not useful to guide the modulation of IFA, possibly because colicky horses usually presented evidence of muscle pathology (from struggling, transportation, recumbent position, and recovery from anaesthesia) that can initially contribute to increased venous blood lactate levels.

Our study showed that PCV and, even more so, TP level, appear to work fairly well in determining the need for fluid therapy according to our results; however, more specific tools are needed. Therefore, in our opinion, both equine surgeons and anaesthetists should strive to identify better means of measuring hydration status in the colic patient. Many horses with colic might benefit from GDFT for volume support, although fluid responsiveness should always be taken into consideration; this is an important concept in human medicine and distinguishes patients who would benefit from fluid resuscitation.[28] Our findings underscore the need for measuring variables that appropriately guide GDFT, although such measurements could be difficult for the horse.[29] Extrapolation of data from other species should be conducted with caution due to risk of overlooking unique physiological horse features, such as cardiac capacity for compensation of hypovolemia, the role of other compartments, including the hind gut's capability to act as a reservoir for fluids, and the peculiar characteristics of fibre digestion, which is responsible for most of the use of water in the equine body.[2]

Our study had some limitations. Given its 'before-and-after' nature, we cannot claim causality between GDFT intervention and observed changes in postoperative outcome. We assigned cases to the GDFT group if one matched case was present in the LFR group. Although randomisation would have been more accurate, it would have required a much larger number of cases. We tried to limit the negative effects of this approach by selecting cases involving the same surgeon, same hospital, and a relatively short time frame. The small number of horses in each group, although sufficient for study power, was a limitation in assessing the validity of our protocols. We chose to match the cases very closely because it is probably of little significance to generally include 'colic cases' when evaluating medical and surgical treatments that are applied to diseases that occur in different anatomical sites, have different aetiologies, and show different clinical features. Thus, this limitation may also be regarded as a strength because we tried to examine the effects of therapy on a group of pathologies presenting very similar features and problems.

Because many metabolic changes and the resultant necessity for intensive therapy are caused by the duration of the obstruction and progression of the pathology, matching for the duration of clinical signs allowed us to compare horses that were as similar in metabolic (hence fluid) derangements as possible. Nevertheless, a greater emphasis on the location of the diseases (proximal/distal jejunum, ileum) than on the pathology could have yielded a more accurate comparison. In fact, horses with the same pathology (e.g. strangulating lipoma) and similar duration of clinical signs, but with different obstruction sites (distal/proximal jejunum) may show very different pathologic and metabolic features.

The parameters used to modulate IV fluid administration, although widely used in clinical practice, were incomplete. Urine output monitoring, serial measures of creatinine and urine-specific weight were not available in a sufficient number of cases selected for the study; adding them to our analysis may have yielded different results.

The long-term survival of our cases was in accordance with the findings of other studies,[29] and although the survival was higher in the GDFT group, the small number of horses in the study prevented us from conclusively stating that GDFT was more effective than the liberal regimen.

In conclusion, implementing an intraoperative GDFT protocol was feasible in our tertiary medical centre. Although our results did not allow us to detect a statistically significant positive effect of GDFT compared with our past practice, the individualisation of fluid therapy did comply with the fluid needs of horses recovering from colic surgery and could help minimise cost due to the reduced amount of fluid administered and the shorter hospital stay. Further studies are needed to understand the correct hydration strategy, define when hydration balance is achieved, and determine if other parameters could be used to better evaluate fluid administration at admission, during anaesthesia, and after colic surgery.

Funding and competing interests statement:

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No competing interests have been declared

Manufacturers details

a) GIA 80, Medtronic Italia S.p.A., Milano, Italy
b) Polysorb, Medtronic Italia S.p.A., Milano, Italy
c) Monosof, Covidien Italia, Segrate Milano, Italy
d) Aagent, Fatro SpA, Ozzano Dell’Emilia, Italy
e) Prontocill, Fatro SpA, Ozzano Dell’Emilia, Italy
f) Meglufen, Izo srl, Brescia, Italy
g) CapH, Fatro SpA, Ozzano Dell’Emilia, Italy

	Case #	Age	Breed	Sex	Weight (kg)	Hours since last seen normal	Diagnosis at surgery	Type of anastomosis	Length of resection (m)	Duration of surgery (min)	Length of hospitalisation (days)
GDFT	1a	8	SB	M	430	6–12	Inguinal hernia	JJ-ETE	0.5	140	10
	2a	10	Sella italiano	F	418	12–18	Ileo-caecal intussusception	JCE-STS	1.5	145	7
	3a	20	Quarter horse	G	438	12–18	Pedunculated lipoma	JJ-ETE	1.5	135	8
	4a	12	Selle francaise	G	568	6–12	Pedunculated lipoma	JJ-ETE	1.5	130	8
	5a	13	Sella italiano	G	512	12–18	Epiploic foramen entrapment	JCE-STS	2.5	125	8
	6a	8	Sella italiano	F	430	18–24	Jejunal volvulus	-	0	100	7
	7a	8	Paint	G	410	6–12	Epiploic foramen entrapment	JJ-ETE	4	130	11
	8a	2	TB	M	412	12–18	Epiploic foramen entrapment	JCE-STS	3.5	195	8
	9a	13	Sella italiano	F	490	6–12	Pedunculated lipoma	JJ-ETE	2	120	9
	Mean+/-SD	**10.44+/-4.9**							**1.7+/-1.36**	**135.6+/-25.8**	**8.4+/- 1.3 ***
	Median (range)				**430 (410-568)**						
	Case #	**Age**	**Breed**	**Sex**	**Weight (kg)**	**Hours since last seen normal**	**Diagnosis at surgery**	**Type of anastomosis**	**Length of resection (m)**	**Duration of surgery (min)**	**Length of hospitalisation (days)**
LFR	1b	5	Sella italiano	M	488	6–12	Inguinal hernia	JJ-ETE	1	145	9
	2b	1	Arab	M	210	12–18	Ileo-caecal intussusception	JCE-STS	3	120	10
	3b	18	Arab	F	450	12–18	Pedunculated lipoma	JJ-ETE	2	140	8
	4b	14	Argentinian	G	470	6–12	Pedunculated lipoma	JJ-ETE	1.5	140	11
	5b	4	Standardbred	F	500	12–18	Epiploic foramen entrapment	JCE-STS	2	135	10
	6b	18	Show Pony	G	395	18–24	Jejunal volvulus	-	0	140	8
	7b	11	Sella italiano	G	550	6–12	Epiploic foramen entrapment	JJ-ETE	3	125	14
	8b	18	Dutch warmblood	G	597	12–18	Epiploic foramen entrapment	JCE-STS	4	125	15
	9b	17	Show Pony	G	350	6–12	Pedunculated lipoma	JJ-ETE	1.5	135	11
	Mean+/-SD	**1.8+/-1.3**								**133.9+/-8.6**	**10.5+/-2.6 ***

	median (range)		**470 (210-597)**

Table 1. Data on signalment, history, and surgery of the two groups of horses. *, p=0,001. *Type of anastomosis*: JJ-ETE jejunojejunal end-to-end, JCE-STS jejunocaecal side-to-side, *Technique:* HS handsewn, ST stapled

	PCV (%)	TP level (g/dl)	HR (bpm)	Venous blood lactate level (mmol/l)	Reflux (l/100kg)
GDFT	37.33+/-6.9	6.66+/-0.84	66+/-18	13.93+/-5,45	0.79+/-1.19
Liberal	42+/-6.24	6.73+/-0.94	70+/-17	13.54+/-4.57	0.61+7-0.66

Table 2. Preoperative haematological and clinical parameters of the two groups of horses

List of figure legends

Figure 1. Quantity of crystalloids administered pre-and intra-operatively to re-establish blood volume (unpaired t-test, p=0.74)

Figure 2. Quantity of gastric reflux at admission per 100 kg BW in the two groups of horses (Mann-Whitney test, p=0.94).

Figure 3. Quantity of POR per 100 kg BW in the two groups of horses (Mann-Whitney test, p=0.45).

Figure 4. Postoperative intravenous fluid administration in the two groups of horses:

A. Quantity of IV crystalloids (lactated Ringer's solution) administered per kg BW (Mann-Whitney test, p=0.0006)
B. Days of IV crystalloids (lactated Ringer's solution) administration (Mann-Whitney test, p=0.0002)

Figure 5. Postoperative oral water intake in the two groups of horses:

A. First time to voluntary oral water intake (Unpaired t-test, p=0.4)
B. Quantity of spontaneous water intake per kg BW per day (t-test, * p=0.03)

Figure 6. Clinical and haematological parameters in the two groups of horses pre-, intra- and postoperatively (t-test):

A. PCV (%)
B. Total protein level (g/dl)
C. Heart rate (bpm. * p=0.02, ** p=0.03, # p=0.049, # p=0.049)
D. Blood venous lactate level (mmol/l. * p=0.002)

References

1. Muir WW, Ueyama Y, Noel-Morgan J, et al. A systematic review of the quality of IV fluid therapy in veterinary medicine. *Frontiers Veterinary Sciences* 2017;4:127.
2. Freeman DE, Mooney A, Giguère S, et al. Effect of feed deprivation on daily water consumption in healthy horses. *Equine Veterinary Journal* 2020;9.
3. Raftery AG, Morgan RA, MacFarlane PD. Perioperative trends in plasma colloid osmotic pressure in horses undergoing surgery. *J Vet Emerg Crit Care* 2016;26:93-100.
4. Espinosa P, Le Jeune SS, Cenani A, et al. Investigation of perioperative and anesthetic variables affecting short-term survival of horses with small intestinal strangulating lesions. *Veterinary Surgery* 2017;46:345-353.
5. Bragg D, El-Sharkawy AM, Psaltis E, et al. Postoperative ileus: recent developments in pathophysiology and management. *Clin Nutr* 2015;34:367–376.
6. Marjanovic G, Villain C, Juettner E, et al. Impact of different crystalloid volume regimes on intestinal anastomotic stability. *Ann Surg* 2009;249:181–185.
7. Brandstrup B1, Tønnesen H, Beier-Holgersen R, et al. Danish Study Group on Perioperative Fluid Therapy. Effects of intravenous fluid restriction on postoperative complications: comparison of two perioperative fluid regimens: a randomized assessor-blinded multicenter trial. *Ann Surg* 2003;238(5):641-8.
8. Freeman D. Post-operative reflux–a surgeon's perspective. *Equine Veterinary Education* 2018;30:671-680.
9. Merritt AM, Blikslager AT. Post operative ileus: to be or not to be?. *Equine Veterinary Journal* 2008;40: 295-296.
10. Hoaglund EL, Hess AM, Hassel DM. Retrospective evaluation of the effect of intravenous fluid administration on development of postoperative reflux in horses with colic (2004-

2012): 194 horses. *J Vet Emerg Crit Care (San Antonio)*. 2018;28(6):566-572. doi:10.1111/vec.12776

11. Bateman RM, Sharpe MD, Jagger JE, et al. 36th International Symposium on Intensive Care and Emergency Medicine: Brussels, Belgium. 15-18 March 2016 [published correction appears in Crit Care. 2016 Oct 24;20:347]. *Crit Care*. 2016;20(Suppl 2):94. Published 2016 Apr 20. doi:10.1186/s13054-016-1208-6
12. Scheeren TW, Wiesenack C, Gerlach H, Marx G. Goal-directed intraoperative fluid therapy guided by stroke volume and its variation in high-risk surgical patients: a prospective randomized multicentre study. *J Clin Monit Comput*. 2013;27(3):225-233. doi:10.1007/s10877-013-9461-6
13. Zakhaleva J, Tam J, Denoya PI, Bishawi M, Bergamaschi R. The impact of intravenous fluid administration on complication rates in bowel surgery within an enhanced recovery protocol: a randomized controlled trial. *Colorectal Dis*. 2013;15(7):892-899. doi:10.1111/codi.12180
14. Calvo-Vecino JM, Ripollés-Melchor J, Mythen MG, et al. Effect of goal-directed haemodynamic therapy on postoperative complications in low-moderate risk surgical patients: a multicentre randomised controlled trial (FEDORA trial). *Br J Anaesth*. 2018;120(4):734-744. doi:10.1016/j.bja.2017.12.018
15. Marqués FJ, Higgins S, Chapuis R, Waldner C. The Effect of Inadequate Presample Blood Volume Withdrawal from Intravenous Catheter and Extension Sets on Measured Circulating L-Blood Lactate Concentration in Horses Receiving Lactated Ringer's Solution. *J Vet Intern Med*. 2017;31(1):51-54. doi:10.1111/jvim.14623
16. Archer DC. Colic surgery: keeping it affordable for horse owners. *Vet Rec*. 2019;185(16):505-507. doi:10.1136/vr.l6062
17. Freeman DE. Fifty years of colic surgery. *Equine Vet J*. 2018;50(4):423-435. doi:10.1111/evj.12817

18. Uemura K, Tatewaki M, Harris MB, et al. Magnitude of abdominal incision affects the duration of postoperative ileus in rats. *Surg Endosc*. 2004;18(4):606-610. doi:10.1007/s00464-003-8161-6

19. Wind J, Polle SW, Fung Kon Jin PH, et al. Systematic review of enhanced recovery programmes in colonic surgery. *Br J Surg*. 2006;93(7):800-809. doi:10.1002/bjs.5384

20. Story SK, Chamberlain RS. A comprehensive review of evidence-based strategies to prevent and treat postoperative ileus. *Dig Surg*. 2009;26(4):265-275. doi:10.1159/000227765

21. Freeman DE. Post operative ileus (POI): another perspective. *Equine Vet J*. 2008;40(4):297-298. doi:10.2746/042516408X302528

22. Freeman DE, Schaeffer DJ, Cleary OB. Long-term survival in horses with strangulating obstruction of the small intestine managed without resection. *Equine Vet J*. 2014;46(6):711-717. doi:10.1111/evj.12216

23. Blikslager AT. Gastric impaction and large colon volvulus: Can one lead to the other? *Equine Vet Educ*. 2015;27: 460-461. doi:10.1111/eve.12417

24. Valle E, Giusto G, Penazzi L, et al. Preliminary results on the association with feeding and recovery length in equine colic patients after laparotomy. *J Anim Physiol Anim Nutr (Berl)*. 2019;103(4):1233-1241. doi:10.1111/jpn.13102

25. Underwood C, Southwood LL, Walton RM, Johnson AL. Hepatic and metabolic changes in surgical colic patients: a pilot study. *J Vet Emerg Crit Care (San Antonio)*. 2010;20(6):578-586. doi:10.1111/j.1476-4431.2010.00597.x

26. Tennent-Brown B. Blood lactate measurement and interpretation in critically ill equine adults and neonates. *Vet Clin North Am Equine Pract*. 2014;30(2):399-viii. doi:10.1016/j.cveq.2014.04.006

27. Edner AH, Nyman GC, Essén-Gustavsson B. Metabolism before, during and after anaesthesia in colic and healthy horses. *Acta Vet Scand*. 2007;49(1):34. Published 2007 Nov 15. doi:10.1186/1751-0147-49-34

28. Marik PE, Lemson J. Fluid responsiveness: an evolution of our understanding. *Br J Anaesth*. 2014;112(4):617-620. doi:10.1093/bja/aet590

29. Gardner A, Dockery A, Quam V. Exploratory Celiotomy in the Horse Secondary to Acute Colic: A Review of Indications and Success Rates. *Top Companion Anim Med*. 2019;34:1-9. doi:10.1053/j.tcam.2018.11.001