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Original Article

Preliminary results on the association with feeding and recovery length in equine colic patients after laparotomy

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Summary

Colic is a serious disease for horses and the nutritional management of post-operative colic patients is an extremely important field. The aim of this retrospective study was to analyse the different factors, especially related to nutritional management, that may be associated with recovery length during hospitalization after a surgical intervention for colic, using a multivariate model. Data were collected from the records of horses presented to two hospitals and undergoing surgery for colic. The length (days) of recovery was the outcome of interest and was taken into account as a reference parameter (short, medium, long). The parameters collected (patient details, preoperative clinical and laboratory examinations, postoperative parameters and post-surgery nutritional parameters) were subjected to multivariate analysis (MCA and PCoA). A ranking class dataset was used to calculate Kendall's tau correlation of the length of recovery with respect to other parameters. Descriptive statistic to identify differences in the recovery length among groups (Kruskall-Wallis and Dunn’s Multiple Comparison Test) was also performed. P value was set at <0.05. Groups were not different in preoperative clinical parameters (BCS, PCV, total protein), postoperative parameters (time to 1st defecation, time to the end of IV fluid therapy and time to first water drinking, anaesthesia) and patient details (age). The comparison among groups revealed differences on the post-surgical nutritional parameters. Horses with short recovery consumed higher % of DM as forages in the 24 h compared with the horses that have long recovery and reach the minimum DM intake in a shorter period. Both Kendall and MCA analysis confirmed that the time to first feeding had a positive association with the length of recovery. Only 37 horses undergoing colic surgery were included in the study. From a clinical standpoint, this study has shown which nutritional parameters are associated with short recovery.

Keywords: Colic; Nutrition; Surgery; Management; Multivariate analysis; Welfare

Introduction

The reported prevalence of colic in horses ranges between 4.2 (Traub-Dargatz *et al.*, 2001) and 10.6 cases per 100 horse-years (Tinker *et al.*, 1997). Seven to 10% of colic events are fatal in the absence of surgical intervention (Proudman, 1992; Hillyer *et al.*, 2001]. Colic has one of the highest mortality rates (Traub-Dargatz *et al.*, 2001) and, with the exception of musculoskeletal injuries and old age, is the main cause of death in some horse populations (USDA, 2005).

Both individual intrinsic and management factors can predispose a horse to colic. Domestic horses are commonly subjected to frequent changes in feed and to diets containing a high level of non-structural carbohydrates and low fibre. In particular, performance horses are often fed starch- and sugar-rich feedstuffs and minimal forage. Such concentrated diets greatly reduce food consumption time, meaning that the horse spends much longer periods without ingesting feed (Clarke *et al.*,1990; Houpt, 1990). In addition, when horses are fed diets other than a high-fibre one, the profile of their microbial population changes, increasing the risk of alterations in the fermentation processes and of metabolic disorders (Julliand *et al.*, 2001; Daly *et al.*, 2012; Dougal *et al.*, 2014). Equines appear to have a small "microbial core" in the hindgut (Costa *et al.*,2015) and this may help explain why horses are susceptible to microbial disruption and consequent gastrointestinal disorders (Dougal *et al.*, 2013).

According to Mair (2013) few studies have evaluated post operatory feeding practice in order to restore the normal bowel function; even if the number of colic cases undergoing surgery is high, only a small amount of data are available to understand the association between feeding and medical patterns and horse recovery rate during the hospitalization.

The aim of this preliminary retrospective study was, therefore, to analyse which factors, especially related to nutritional management, are associated with the recovery of the animal during hospitalization after a surgical intervention for colic. We think that this preliminary data could bring new information in a very important field still not well investigated.

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Materials and methods

Patient selection

Data were collected from records of surgical colic cases (performed between the years 2012-2017) from the hospitals of the Department of Veterinary Science of the University of Turin (Italy) and of the Department of Veterinary Medicine of the University of Lisbon (Portugal). A total of 37 horses undergoing colic surgery were included in the study and no patient follow-up after hospital discharge was performed.

Collection of analysed parameters and codification into classes

The information collected from case records were collected during the recovery period (every four hours) and include: patient details (age, gender, breed) and results of preoperative clinical and laboratory examinations (body condition score, BCS, on a 9 point scale (Henneke *et al.*, 1983); packed cell volume, PCV, in L/L; total proteins, PT, in g/L). The postoperative parameters collected after surgery were*:*

- time (h) to first defecation;
- time (h) to the end of IV fluid therapy;
- time (h) to first water drinking after the end of IV fluid therapy;
- intestinal motility at 8:00 a.m. on the 2nd day after surgery;
- intestinal motility at 8:00 a.m. on the 4th day; intestinal motility was assessed through auscultation (according to Sanchez (2010));
- Risk Class (RC) categories; abdominal surgeries were classified at the end of surgery as: low, medium, or high risk (Figure 1);

- anaesthesia length: duration of the induced anaesthesia in minutes;
- post-surgery complications were divided into medical complications (no complications, ileus, site of impaction, no complications, ileus, site of impaction, reflux considered as more than 2 litres of fluids at nasogastric intubation and others) and nutritional complications (no complications, water rejection, food rejection, others);

The nutritional parameters assessed after surgery were:

- time (h) to the first meal (according to the types of feed consumed) (see Table 1 for a complete description of the feed offered);
- % of dry matter (DM) intake as forage (hay and/or grass)/body weight (BW, kg) in the first 24 h after surgery, and on the 2nd day after surgery (48-72 h);
- % of total DM intake based on all the feed consumed (forages and horse feed)/BW (kg) on the 2nd and the 4th day after surgery (48-72 h and 96-120 h, respectively);
- proportion between long fibre (hay) and short fibre (fibrous mix) on the 2nd and the 4th day after surgery;
- time (in days) to reach minimum DM intake (in this study it was considered to be 10 g DM/kg BW, according to Geor (2008). Grass intake was also evaluated in the DM calculation, considering that 1 h of grazing approximately corresponded to 0.5 kg of DM (10 minutes = 0.083 kg of DM) (Worth, 2010);
- recovery (days): was judged according to the possibility of the horse to be dischargeable. That was based on the normalization of all clinical parameters for at least 24 hr, the lack of any behavioural signs indicating pain or inappetence and, the patient ability to eat the whole ration provided. It was conventionally set by the clinician at 8 a.m.

Statistical analysis

Statistical analysis was performed using PAST software package (version 2.17) (Hammer *et al.*, 2001). The length (days) of recovery was the outcome of interest for statistical analysis, and was taken into account as a reference parameter. Multiple correspondence analysis (MCA) was used to investigate the correlation between the different parameters and the recovery length.

In order to proceed with this combined analysis, all parameters were transformed into a numeric classification using an optimal scaling process. Briefly, classes were balanced on the basis of bibliographic indications, when present, or based on being lower than the 25% quartile or higher than the 75% quartile. Missing data were codified as “?”.

A ranking class dataset was clustered according to the length of recovery classes by cosine similarity index (supplementary figure is provided to show cosine similarity index). Subsequently, the ranking class dataset was used to calculate the Kendall’s tau correlation coefficient for the recovery length with respect to other parameters. The correlation significance was then assessed according to Bonferroni corrected multiple comparison p-values.

Converted class data were then codified into Dummy variables, i.e., "proxy" variables or numeric stand-ins for qualitative facts in a regression model. The main outcome variable (independent variable), which leads the stratification of the data population, was the length of recovery. From Dummy coded variables, a Burt matrix was generated and used for MCA. Once this procedure had been concluded, PCoA (Principal Coordinates Analysis) was performed directly on the class dataset previously described. The Bray-Curtis dissimilarity matrix was used to ordinate individuals on the plot.

Moreover a descriptive statistic was performed with SPSS Statistic 22 to report the patient details, preoperative clinical and laboratory examination results and the postoperative parameters; after checking normality, a statistical analysis to identify differences among classes of recovery length was performed with non-parametric test (Kruskall-Wallis) and Dunn’s Multiple Comparison Test (P value was set <0.05).

Results

Classes for recovery (short: ≤ 8 days; medium: 9-11 days; and long: ≥ 12 days) were calculated based on the interquartile range and considering the classification made by Sellon and co-workers (2004) in their retrospective study of 31 horses.

Thirty-seven cases survived surgery and were therefore included in the study (30 surgeries were performed at the Turin Veterinary Teaching Hospital and 7 at the Lisbon Veterinary Teaching Hospital).

The frequencies of the patient details data, preoperative clinical and laboratory examination results and the postoperative parameters are shown in Table 2, while in Table 3 are reported the median and interquartile range (IQR) of preoperative, postoperative and nutritional parameters divided in 3 classes according to the length of recovery. No differences among classes were recorded for age, BCS, PCV, total protein, anaesthesia time, time to 1st defecation, time to the end of IV fluid therapy and time to first water drinking.

DM intake as forage/kg BW in the first 24 hr was higher in the short recovery length class compared to the long recovery class where the median value was 0. The % of DM intake as forage in the 2nd day was higher for short recovery length class as compared with medium ($P<0.001$) and long ($P<0.05$). The total DM intake/kg BW in the 2nd day and the 4th day were higher in the short recovery than the long recovery class ($P<0.05$). Time in days to reach the minimum DM in the short recovery group, 6 (4.5-7.5), was significantly different ($P<0.001$) than the long recovery group, 12 (12-15). On the other hand, time to reach minimum DM in the medium group, 7.5 (5-11.5), was significantly shorter compared to the long one ($P<0.05$).

Correlation with recovery length

Correlation data are shown in the last column of Figure 2. Recovery length was negatively correlated with BCS classes: a low BCS was more frequent among horses with a longer postsurgical recovery length, whereas a higher BCS was associated with a reduction in recovery length (Kendall's tau = -0.388; $P < 0.002$).

A negative correlation was also observed for intestine motility on the 2nd day post surgery (Kendall's tau = -0.490) and for % DM intake as forage/kg BW in the first 24 h and on the 2nd day. Horses that received smaller quantities than 0.1 % DM as forage/BW in the first 24 h and 0.3 % DM as forage/BW on the 2nd day after surgery were more subject to longer recovery (Kendall's tau = -0.365 and -0.445, respectively); in addition, negative correlations were observed for % total DM intake/kg BW on the 2nd and the 4th day after surgery (Kendall's tau = -0.476 and -0.452, respectively).

By contrast, significantly positive correlations between recovery length and anaesthesia time (Kendall's tau = 0.367), time to first grass meal (Kendall's tau = 0.425), forage meal (Kendall's tau = 0.421) and time needed to reach minimum DM intake (Kendall's tau = 0.533) were observed.

Multivariate analyses

The MCA plot shows a clear gradient along Axis 1 (horizontal axis), which accounts for almost 70% of explained variability, with low score values for short lengths of recovery (variable score < -0.35) and higher scores for longer lengths of recovery (variable score > 0.6). Accordingly, analysis of the plot reveals the variables that covariate with shorter recovery length and variables that are more recurrent with longer ones.

Long recovery was found to be associated with: young age; a BCS between 3 and 4; complications such as reflux or ileus; reduced intestine motility on the 2nd and the 4th day; food rejection; time to grass meal > 24 h; % total DM intake/kg BW on the 2nd day after surgery < 0.35; % total DM intake/kg BW on the 4th day < 0.6; time to reach minimum DM ≥ 12 days; and use of cereal by-products. Among horse feeds, cereal by-product mix had an adverse association with recovery length. However, a larger number of cases need to be included in this class to confirm this trend.

A short recovery length was associated with: a BCS between 6 and 7.5; anaesthesia time < 120 minutes; normal intestine motility on the 2nd day after surgery; duration of IV fluid therapy < 12 h; other nutritional complications; time to 1st grass meal < 12 h; time to 1st preserved forage meal < 12 h; time to 1st compound feed meal < 24 h; % DM as forage/kg BW in the first 24 h > 0.1; % DM as forage/kg BW on the 2nd day after surgery ≥ 0.3; % total DM intake/kg BW on the 2nd day after surgery > 0.55; % total DM intake/kg BW on the 4th day after surgery > 0.85; and time to reach minimum DM intake < 11 days.

All the other classes were associated with a medium duration of recovery (9-11 days), as gender, haematocrit, total proteins, risk class, time to first defecation and the proportion between long and short fibres did not correlate with a long or short length of recovery.

The graphical distribution of individual horses according to PCoA is shown in Figure 3. The Bray Curtis algorithm was used to evaluate similarity between individuals. In this analysis, the level of variability explained by the first coordinate, which roughly discriminates between short and long recovery times, was about 24%. The distribution of the single individuals belonging to different classes can, nonetheless, be appreciated: the majority of animals enduring a short recovery are on the right hand side of the graphic, while almost all the horses with a long recovery on the left.

Discussion

Comparison among classes of recovery revealed that groups were not different regarding preoperative clinical parameter (BCS, PCV, total protein), postoperative parameter (time to 1st defecation, time to the end of IV fluid therapy and time to first water drinking after) and patient details. Many of them are usually considered as important factors for the recovery of the animals and for this reason a multivariate statistical analyse was used to extrapolate the possible relationships between the recorded variables. Surprisingly, the risk classes adopted in this study did not appear to be directly correlated with the recovery length. On the other hand, shorter anaesthesia duration was associated with shorter recovery length according to MCA scores. Anaesthesia may affect intestinal motility but, when comparing the three classes no differences were identified probably due to the wide interquartile range among each group considered for the comparison.

Also no differences were found among age classes. In the present study, old age (maximum patient age being 19 years) did not negatively affect postsurgical length of recovery. Previous studies have associated old age with a lower survival rate (Reeves *et al.*, 1989; Proudman *et al.*, 2006), but survival was not included as a parameter in the present study. Other authors did not find any association between age and poorer prognosis (Mair & Smith, 2005; Southwood *et al.,* 2008). On the contrary, this retrospective study identified young age (≤ 5 years) as a negative factor, with higher recovery periods found in younger patients. Gender did not appear to be correlated with the length of recovery but this might be due to the disparity in the number of animals included in the different classes. Our study comprised 24 geldings, 9 mares and just 4 stallions.

Body condition score *per se* was not different among classes of recovery. The statistical approach used in the present study however revealed that low BCS was related with longer patient recovery; on the contrary a (moderately) over-weight patient had shorter recovery after abdominal surgery. This could be due to the fact that more fleshy horses have more reserves to mobilize during recovery compared with thin ones.

With respect to the clinical parameters, packed cell volume on admission did not seem to be associated with the length of recovery. The collected data show that the time to first defecation did not covariate with the length of the post-surgery period. This may be due to the fact that some surgeries required the emptying of the hindgut while others did not.

Reduced intestine motility on the 2nd and the 4th day was associated with a longer post-surgery period, while normal motility on the 2nd day was related to a shorter post-surgery period. However, normal intestinal motility on the 4th day was not clearly correlated with a shorter recovery length, possibly because after 4 days patients reached the same level from a clinical point of view, and motility was no longer significant.

For this reason, the condition which is more likely to exert positive influence on recovery length is adequate gut motility in the early phase of the postsurgical period.

As far as post-surgery complications are concerned, ileus is associated with a longer recovery length. This is not surprising considering that several studies have identified ileus as one of the main postsurgical complications with high mortality rate (Cohen *et al.*, 2004; Torfs *et al.*, 2009).

According to Doherty (2009), in human subjects, the use of traditional IV fluid therapy, when compared with a restricted IV administration of fluid and salts, delays the recovery of the gastrointestinal function. In the present study, brief postsurgical IV fluid therapy was associated with a shorter length of recovery, probably because continuous administration of parenteral fluid does not permit the normal compartmentalization of water in the hindgut, thus altering blood osmolality and affecting the normal desire to drink water and eat. According to Freeman *et al.* (2015) overhydrating unfed horses can be detrimental, and interferes with recovery length.

The comparison among classes revealed differences especially on the post-surgical nutritional parameters (Table 3). Horses in the short recovery classes ate higher % DM as forages in the 24 h than the horses that have long recovery and reach the minimum DM intake in a shorter period. Both Kendall and MCA analysis confirmed that the time to first feeding had a positive association with the length of recovery. Horses that were able to eat forages within 12 h after surgery had shorter recovery length. Even if it is likely that horses which recover better from the surgery would start voluntary feeding earlier compared to sick ones, we should also consider that food influences considerably intestinal motility, playing a main role in the reactivation of enterocyte function.

The feeds used in the present study were chosen according to the current literature on colic patients (Geor, 2007; Mair, 2013) and included forages (fresh or preserved) and compound feeds (complementary feeds see Table 1).

According to our results, the type of feed given is an important factor influencing recovery rate. In fact, our study reveals an association between short recovery length and the provision of forages and fibrous mix within 12 h and 24 h, respectively. However the MCA results showed a negative association between length of recovery and the use of horse compound feed based on cereal by-products. The present study may be limited by the fact that just one product was used and was based on wheat bran.

According to our results, there is an association with short recovery length for horses receiving at least 0.1% DM of their BW as forages in the first 24 h post surgery. The corresponding quantity of hay for a 500 kg horse would be equal to 0.5 kg DM. This quantity divided into small meals corresponds to the common feeding regime used in clinical practice that consists of handfuls of hay. Besides, our results show that an association exists when the quantity of forage is increased to at least 0.3 % DM/BW on the 2nd day after surgery. As well, total DM intake higher than 0.55% on the 2nd day after surgery and 0.85 % on the 4th day covariate with a shorter recovery length.

Recently Harris and co-workers (2017) suggested that the minimum quantity of DM given as forage should be 12.5 g DM/kg BW, justifying it with health and ethological aspects related to the horse’s needs. However, this minimum quantity was intended for a healthy horse, and may not be suitable for a postsurgical recovering patient. In this study, we followed previous indications which considered 10 g DM/kg BW as an adequate amount (Geor, 2008). In fact, the degree of gut-filling is a factor that surgeons are concerned about in their post-operative colic patients, particularly during periods of time in which the drinking stimulus is altered.

We are aware that our research may have two limitations. The first is the small number of cases examined, with records from only two hospitals. The second limitation concerns the influence of medical treatments, which was only considered as part of the risk class context and not as a specific parameter. However, this preliminary data can bring new information regarding nutritional management of post-operative colic patients.

Conclusions

From a methodological point of view, we show the adaptability of the MCA and PCoA approaches, and of multivariate analysis in general, and their utility for associating multiple variables. From a clinical standpoint, this study has shown which nutritional parameters (% DM intake as forage/BW, % total DM intake/BW and time to reach minimum DM) are associated with a short recovery period. Therefore it is desirable that feed be introduced as soon as clinical parameters start to improve in order to enhance gastrointestinal well-being and, at the same time, restore intestinal microbiome core.

Animal Ethics Statement

No permits or ethical committee approvals were required for the described study. The owners of the horses gave written consent for all clinical procedures that are part of routine care and quality standard of the involved hospital.

Conflict of interest statement

None of the authors has any financial or personal relationship which could inappropriately influence or bias the content of the paper.

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Table 1

Feed type and minimum and maximum values recorded for nutritional composition according to the feed label

FEED TYPE			TYPICAL ANALYSIS (on DM)						Main ingredients
			DM	CP	CFb	Fat	Ash	FL	
Forages	**Fresh**	**Grass**	17%	13.3-15%	27.2-28%	2.0-2.5%	9.4-9.7%	> 10 cm	Lolium italicum
	Preserved	**Hay**	85%	7-8.8%	33-35%	1.2-2%	6.9-7.7%	> 10 cm	First cut meadow hay
		Haylage	50%	11%	43%	3%	6%	> 10 cm	Lolium
Horse compound feed	**Complementary feed**	**Fibrous mix**	87%	11-13%	22-24%	5-8%	13%	< 2-8 cm	Hay and alfalfa
		Cereal by-product mix	89%	14.5%	11.5%	11.6%	8.9%	Pellet	Wheat bran

DM: Dry Matter; CP: Crude Protein; CFb: Crude Fibre; Ash: Ashes; FL: Fibre Length

Table 2

Parameter frequencies for patient details, preoperative clinical and laboratory examinations, and postoperative parameters (n = 37).

Patient details	n	%
Breed		
Sella Italiano	6	16.2
KWPN (Royal Dutch Sport Horse)	5	13.5
Puro Sangue Lusitano	5	13.5
Argentine	5	13.5
Selle Francais	3	8.1
Arabian	2	5.4
Holstein	2	5.4
Others	9	24.3
Age		
≤ 5 years	4	10.8
5-15 years	25	67.6
≥ 16 years	8	21.6
Gender		
Male	28	75.7
Female	9	24.3

Preoperative clinical and laboratory examinations	n	%
BCS (from 1 to 9)		
≤ 4	8	21.6
4-6	17	46
≥ 6	12	32.4
Haematocrit (L/L)		
< 0.35	11	29.7
0.35-0.39	11	29.7
> 0.40	12	32.4
Missing data	3	8.1
Total serum protein (g/L)		
< 60.0	6	16.2
60.0-69.0	13	35.1
> 69.0	12	32.4
Missing data	6	16.2

Postoperative parameters	n	%
Surgery risk class		
Low (A)	12	32.4
Medium (B)	12	32.4
High (C or D)	13	35.1
Medical complications		
No	22	59.5
Reflux	5	13.5
Post operative ileus	3	8.1
Small intestine impaction	2	5.4
Others	5	13.5
Nutritional complications		
No	21	56.8
Water refusing	10	27
Food refusing	5	13.5
Others	1	2.7

Table 3

Median and interquartile range of the preoperative, postoperative and nutritional parameters in the analyzed cases (n = 37). Values with symbols identify differences <0.001 while values with letters identify differences <0.05 according to Dunn's multiple comparison test

	Length of recovery (in days)		
	Short (<8)	Medium (9-11)	Long (>12)
Age (years)	12 (10.5-14)	10 (5-15)	12.5 (11-17)
BCS (from 1 to 9)	5.75 (4.5-6)	5 (4.5-6)	4 (4-5)
PCV (L/L)	0.375 (0.35-0.41)	0.38 (0.33-0.41)	0.37 (0.33-0.39)
Total Protein (g/L)	69.0 (64.0-74.5)	64.0 (59.0-73.5)	60.0 (47.0-74.0)
Time (min) for anaesthesia	120 (112.5-135)	142.5 (127.5-162.5)	160 (120-185)
Time (h) to 1st defecation	15.5 (7.5-23.5)	11.5 (8-28)	14 (12-24)
End of fluid therapy (h)	0 (0-24)	27.5 (0-42)	113
Time (h) to 1st water drinking after end of fluid therapy	24 (6-39)	19.5 (6-52.5)	4
% DM as forage/BW in the first 24 h	0.090^{a} (0-0.225)	0^{ab} (0-0.16)	0^{b} (0-0)
% DM as forage/BW in the 2nd day	0.415$^{\delta a}$ (0.295-0.545)	0.190$^{\Omega}$ (0.070-0.360)	0.110^{b} (0-0.180)
% total DM intake/BW in the 2nd day	0.635^{a} (0.495-0.815)	0.420^{ab} (0.165-0.600)	0.420^{b} (0-0.440)
% total DM intake/BW in the 4th day	0.890^{a} (0.770-1.215)	0.535^{ab} (0.235-1.065)	0.430^{b} (0-0.740)
Time to reach minimum DM (days)	6$^{a\delta}$ (4.5-7.5)	7.5^{a} (5-11.5)	12$^{b\Omega}$ (12-15)

Figure legends

Fig. 1 Risk class categories and related lesions (Valle *et al.*, 2016)

Fig. 2 Numeric classification by scaling process for the class division, Kendall's tau correlation coefficient to length of recovery and classification according to MCA scores
Notes: Time is expressed in hours. Classes were balanced on the basis of bibliographic indications (BCS according to Hennecke *et al.* (1983); Hematocrit accordig to Proudman *et al.*, (2006); Total Proteins according to Mair & Smith (2005); Type of surgery according to Valle *et al.* (2016)), when present, or based on lower 25% or higher 75% quartiles. Arrows were assigned based on MCA score: variable score < -0.35 associated with short recovery have ↓; variable score > 0.6 associated for long recovery have ↑; Classes with no arrows are associated with medium recovery length (9-11 days).

Fig. 3 PCoA analysis with Bray-Curtis dissimilarity coefficient to evaluate similarity between individuals (red dots: ≥ 12 days; yellow dots: 9-11 days; green dots: ≤ 8 days)

Supplementary Information Items

Fig. 4 (supplementary). Clustering of analyses in recovering horses according to Cosine similarity (red: ≥ 12 days; black: 9-11 days; green: ≤ 8 days)