

# Risk factors associated with development of diarrhea in horses after celiotomy for colic: 190 cases (1990–1994)

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**Objective**—To determine the incidence of and risk factors for developing diarrhea in horses after celiotomy for colic.

**Design**—Retrospective cohort study.

**Animals**—357 adult horses that had celiotomy for colic at the teaching hospital between Jan 1, 1990 and Sep 1, 1994.

**Procedure**—Medical records of horses that had celiotomy for colic were reviewed to abstract information regarding development of diarrhea, signalment, history, and treatment.

**Results**—In horses that had celiotomy for colic, the incidence of diarrhea was 53.2% (190/357). Using multiple logistic regression, horses with a disorder of the large intestine were approximately twice as likely to develop diarrhea after celiotomy as horses that had surgery for other types of intestinal lesions ( $P < 0.001$ ). Even after accounting for the effects of large intestinal surgery, horses that also had an enterotomy were approximately 1.5 times as likely to develop diarrhea ( $P = 0.042$ ). Diarrhea in horses associated with duration  $> 2$  days, isolation of *Salmonella* spp from feces, or leukopenia was categorized as being severe. Incidence of severe diarrhea was 27.5% (98/357). Using multiple logistic regression, horses that had surgery of the large intestine were approximately 2.5 times as likely to develop severe diarrhea after celiotomy as horses that had surgery for other types of intestinal lesions ( $P = 0.006$ ). In horses that had celiotomy for colic, those that were fed grass hay were approximately half as likely to develop severe diarrhea as were horses that were not fed grass hay ( $P = 0.018$ ).

**Clinical Implications**—Although the risk factors identified for the development of diarrhea are not alterable, knowledge of them will enable clinicians to better advise clients and to better prepare for medical management of horses after surgery. (*J Am Vet Med Assoc* 1996;209:810–813)

Complications following celiotomy for colic in horses include ileus, peritonitis, endotoxic shock, intestinal infarction, incisional dehiscence, wound infection, laminitis, disseminated intravascular coagulation, thrombophlebitis, intra-abdominal adhesions, myopathies, neuropathies, long-bone fractures, renal failure, and diarrhea.<sup>1-7</sup> Results of other reports on complications after colic surgery indicate that diarrhea is not an important cause of death.<sup>1-7</sup> Our clinical impression has been that diarrhea is a common and important cause of disease after surgery in horses that

have celiotomy for colic. Incidence of diarrhea among 57 horses with nonstrangulating colonic obstruction requiring surgical correction and evacuation of the large colon, cecum, or both was 61.4%.<sup>8</sup> To our knowledge, the development of diarrhea among horses that have celiotomy for colic has not been described. The purpose of the study reported here was to determine the incidence of and risk factors associated with the development of diarrhea in a population of horses that had celiotomy for colic at our clinic.

### Criteria for Selection of Cases

Medical records of all horses older than 1 year of age that had celiotomy for colic at the teaching hospital between Jan 1, 1990 and Sep 1, 1994 were reviewed. Only medical records from horses that had survived at least 3 days after abdominal surgery were included in the study.

The medical record of each horse was reviewed to extract the following information: (1) date of admission, (2) age, (3) breed, (4) sex, (5) weight, (6) clinical signs at the time of admission (colic or other), (7) duration of clinical signs prior to admission, (8) type of feed in diet, (9) amount of time horse was on pasture (100% of time, 51 to 99%, 50%,  $< 50\%$ , or never), (10) route of administration, type, and duration of treatment with antibiotics before surgery, (11) results of hematologic and serum biochemical analysis (concentrations of total protein, albumin, hemoglobin, blood urea nitrogen, and creatinine) before surgery, (12) results of analysis of peritoneal fluid (color, transparency, and concentration of WBC, RBC, total protein, and fibrinogen) before surgery, (13) whether the lesion found at surgery affected the large intestine (displacement, impaction, enterolithiasis, or torsion of the large intestine) or other parts of the intestinal tract (small intestine, stomach), (14) whether an enterotomy was performed, (15) whether intestinal resection and anastomosis was performed, (16) duration of surgery, (17) whether drainage was found from the wound after surgery, (18) surgical outcome (discharged from hospital alive, died, or euthanized), (19) whether diarrhea as a new problem (ie, incident case of diarrhea) was recorded in the medical record at any time after surgery and prior to discharge, (20) number of days after surgery when diarrhea was first observed, (21) duration of diarrhea (days), (22) whether the horse was febrile at onset of diarrhea, (23) whether the horse was leukopenic at the onset of diarrhea, and (24) whether *Salmonella* spp were isolated from fecal samples. For purposes of this study, diarrhea in horses was defined as having passed unformed feces 3 times in succession. In horses with diarrhea, a subgroup of horses considered to have severe diarrhea

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was also identified by including those horses that had diarrhea for > 2 days, had been leukopenic at the time of onset of diarrhea, or that had *Salmonella* spp isolated from a fecal sample.

### Statistical Analysis

Incidence of diarrhea and the 95% confidence interval for this estimate were calculated using exact binomial methods.<sup>9</sup> For descriptive statistics, categorical data were reported as percentages and continuous data were described by medians and interquartile range (ie, range from the first to the third quartile). The relationship between the dichotomous outcome of diarrhea and independent categorical variables (eg, breed, whether a large intestinal lesion was identified) was examined using two- and multi-way contingency comparisons; the  $\chi^2$  and Fisher's exact tests were used to compare proportions.<sup>9</sup> The relationship between development of diarrhea and independent continuous variables (eg, age, duration of surgery) was examined by use of Wilcoxon's rank sum test.<sup>9</sup> The crude measure of association between single putative risk factors and diarrhea was expressed as the relative odds. Relative odds were obtained from the univariate logistic regression.<sup>10</sup> Confidence limits for the univariate odds ratios were derived using the maximum-likelihood estimators.<sup>10</sup> Variables associated ( $P \leq 0.10$ ) with diarrhea in univariate analyses were included in the stepwise multiple logistic regression model<sup>10</sup> to obtain estimates of the magnitude and direction of the association of diarrhea with multiple factors and to obtain estimates for single variables adjusted for the effects of other variables. Bivariate interaction terms were considered for all variables included in the multiple logistic regression models. Goodness-of-fit of the logistic models was assessed by use of the method of Hosmer and Lemeshow,<sup>10</sup> and a  $P$  value  $\leq 0.05$  was suggestive of a poor fit. For multivariate analyses, a value of  $P \leq 0.05$  was considered significant. These same methods were used to compare the subgroup of horses categorized as having severe diarrhea with horses that did not develop diarrhea after surgery.

### Results

During the study period, 374 adult horses that had celiotomy for colic at the clinic were identified. Seventeen horses had died or were euthanatized during the 3 days after surgery and were, therefore, excluded from the study. Thus, 357 horses were eligible for inclusion in this study. Of these, 190 (53.2%; 95% confidence interval, 48.0 to 58.4%) had developed diarrhea after surgery. Diarrhea was detected between 0 (ie, same day) and 8 days after surgery (median, 1 day). Duration of diarrhea ranged from 1 to 15 days (median, 2 days). Diarrhea lasted > 2 days in 81 (32.4%) of the horses.

There were not any significant differences between horses that developed diarrhea after surgery and those that did not with regard to age, sex, and breed. Horses with diarrhea ranged in age from 1 to 21 years (median, 7 years), and horses without diarrhea ranged in age from 1 to 18 years (median, 8 years). The percentages of intact male, gelding, and female horses affected (22, 24, and 34%, respectively) were the same

for both groups of horses. Quarter Horse was the most common breed of horses with diarrhea (100/190; 52.6%) and also without diarrhea (76/167; 45.5%). The majority of horses in both groups (182/190 horses with diarrhea and 151/167 horses without diarrhea) were admitted for evaluation of colic. There was not a significant difference in the distribution of weights of horses that developed diarrhea (median, 484 kg; interquartile range, 436 to 523 kg) and those that did not (median, 461 kg; interquartile range, 409 to 520 kg).

With regard to diet, there was not a significant difference in the percentage of horses that were fed pelleted concentrate, grain, grass hay, alfalfa hay, or alfalfa pellets between horses with diarrhea and horses without diarrhea. There also was not a significant difference between horses with diarrhea and horses without diarrhea with regard to the amount of time they were on pasture (category of percent of time pastured). There was not a significant difference between the 2 groups of horses with regard to the duration of clinical signs prior to admission. The proportion of horses with clinical signs > 48 hours prior to admission was 9% in both groups.

There were not any significant differences between groups with regard to results of hematologic evaluation, serum biochemical analysis, or peritoneal fluid analysis before surgery. Three horses in each group were found to be neutropenic before surgery. Ninety-eight percent of horses with and without diarrhea received antibiotics before surgery. There were not any significant differences between the horses with diarrhea and horses without diarrhea with regard to the type, duration, or route of administration of antibiotics given before surgery.

Duration of surgery did not differ significantly between horses with diarrhea (median, 2.2 hours; interquartile range, 1.7 to 2.8 hours) and those without diarrhea (median, 2.2 hours; range, 1.7 to 2.6 hours). Surgery involving the large intestine was significantly ( $P < 0.001$ ) more common in horses with diarrhea (90/190; 47.4%) than in horses without diarrhea (45/167; 27.0%). Enterotomies were significantly ( $P = 0.004$ ) more common in horses that subsequently developed diarrhea (109/190; 57.4%) than in those that did not develop diarrhea (70/167; 41.9%). The percentage of horses that had intestinal resection and anastomosis did not differ significantly between horses with diarrhea (17.9%) and those without (22.1%).

The percentage of horses with and without diarrhea that had incisional drainage found after surgery was the same (16.8%). The percentage of horses that were discharged from the hospital alive did not differ significantly between horses with and without diarrhea (91.6% and 92.8%, respectively). Death was attributed to diarrhea in 1 horse only.

Surgery involving the large intestine and enterotomy remained significantly associated with diarrhea (Table 1). Inclusion of both variables in the logistic regression model provided the best fit; interaction between the 2 variables was not significant.

A CBC was submitted at the onset of diarrhea for 67 of 190 (35.3%) horses with diarrhea. Of these, 30 (44.8%) horses were leukopenic. Feces from 38 horses were submitted for bacteriologic culture, from which

Table 1—Multiple logistic regression analysis of factors associated with the development of diarrhea after surgery in 357 horses that had celiotomy for colic: 190 horses observed with diarrhea and 167 horses without diarrhea

Variable	Coefficient	95% CI for coefficient	P value for coefficient	Odds ratio for variable	
				Point estimate	95% CI for odds ratio
Surgery of large intestine	0.786	0.329, 1.243	0.001	2.19	1.39, 3.47
Enterotomy performed	0.454	0.017, 0.891	0.042	1.57	1.02, 2.44
Intercept	-0.385	-0.704, -0.066	0.019	ND	ND

Hosmer and Lemeshow goodness-of-fit statistic = 6.7888 with 8 degrees of freedom ( $P = 0.5596$ ).  
CI = confidence interval; ND = not determined.

Table 2—Multiple logistic regression analysis of factors associated with developing severe diarrhea after surgery in horses that had celiotomy for colic: 98 horses observed with severe diarrhea and 167 horses without diarrhea

Variable	Coefficient	95% CI for coefficient	P value for coefficient	Odds ratio for variable	
				Point estimate	95% CI for odds ratio
Surgery of large intestine	0.952	0.280, 1.624	0.006	2.59	1.32, 5.07
Grass hay fed in diet	-0.828	-1.500, -0.156	0.018	0.47	0.22, 0.86
Intercept	-0.385	-0.704, -0.066	0.019	ND	ND

Hosmer and Lemeshow goodness-of-fit statistic = 9.2409 with 8 degrees of freedom ( $P = 0.3224$ ).  
See Table 1 for key.

*Salmonella* spp were isolated from 21 (55.3%) samples. A subgroup of 98 (27.5%; 95% confidence interval, 22.9 to 32.1%) horses had diarrhea that was considered to be severe because it lasted more than 2 days ( $n = 81$ ), the horse was leukopenic at the time of onset of diarrhea ( $n = 30$ ), or the horse had *Salmonella* spp isolated from a fecal sample ( $n = 21$ ). Seventeen horses that were either leukopenic ( $n = 11$ ), had *Salmonella* spp isolated from fecal samples ( $n = 5$ ), or both ( $n = 1$ ) had diarrhea that lasted  $\leq 2$  days.

The subgroup of 98 horses considered to have severe diarrhea were compared with the horses without diarrhea to identify risk factors for the development of severe diarrhea. Univariate analyses were performed as described previously, and only the following factors were identified as being associated with development of severe diarrhea ( $P \leq 0.10$ ): surgery of the large intestine, whether an enterotomy was performed, whether the horse was fed coastal hay, duration of surgery, and PCV. Surgery of the large intestine was significantly ( $P < 0.001$ ) more common in horses with severe diarrhea (41/98; 41.8%) than in horses without diarrhea (45/167; 27.0%). Enterotomies were more commonly associated ( $P = 0.10$ ) with horses that subsequently developed severe diarrhea (51/98; 52.0%) than with horses that did not develop diarrhea (70/167; 41.9%).

Whether grass hay was fed was recorded in the medical record for 66 (67.3%) of the subgroup of horses considered to have severe diarrhea and 107 (64.1%) of the horses without diarrhea. The percentage of horses with severe diarrhea that were fed grass hay (40/66; 60.6%) was significantly ( $P = 0.025$ ) less than that for horses without diarrhea (82/107; 76.6%).

The duration of surgery was longer ( $P = 0.08$ ) in the subgroup of horses considered to have severe diarrhea (median, 2.4 hours; interquartile range, 1.8 to 2.9 hours) than in horses without diarrhea (median, 2.2 hours; interquartile range, 1.6 to 2.6 hours). Packed cell volumes were higher ( $P = 0.10$ ) in horses with severe diarrhea (median, 38%; interquartile range, 33 to 43%) than in horses without diarrhea (median, 36%; interquartile range, 30 to 42%).

Stepwise multiple logistic regression analysis was performed to evaluate the association between development of severe diarrhea and the following variables: surgery of the large intestine, whether an enterotomy was performed, whether the horse was fed coastal hay,

duration of surgery, and PCV. Only surgery of the large intestine and whether the horse was fed coastal hay were significantly associated with development of severe diarrhea (Table 2); interaction between the 2 variables was not significant.

### Discussion

Although other reports have reviewed complications after surgery associated with celiotomy for colic,<sup>1-7</sup> the authors are not aware of the results of reports indicating the incidence of diarrhea in horses recovering from colic surgery. The incidence of diarrhea in horses that had surgery for colic and survived more than 3 days in our study was 53.2%. The incidence of severe diarrhea associated with isolation of salmonellae from feces, leukopenia, or duration of diarrhea  $> 2$  days was 27.5%.

Because our data were obtained from medical records, we recognize that there may be biases in our study that are inherent to all retrospective studies. We selected medical records of horses on the basis of celiotomy for colic, from which we determined the incidence of diarrhea. The high incidence of diarrhea in our population might have been attributable to the large number of horses that had colonic surgery,<sup>8</sup> or to our definition of diarrhea. Horses were considered to have had diarrhea if passage of unformed feces was recorded in the record  $\geq 3$  times. We believe that the recording of diarrhea in the medical records was accurate because all horses were managed after surgery in our intensive care unit. The number of defecations and consistency of feces were recorded on treatment forms for all horses in the intensive care unit. Existence of diarrhea for each horse was determined from notes recorded in the medical record and the intensive care unit record. Therefore, a surveillance bias (ie, a bias arising from horses being monitored differently) or a misclassification of exposure or outcome status (eg, misclassifying a horse as not having diarrhea when it indeed had diarrhea) seems improbable.

To identify horses that had diarrhea that was considered to be severe, we conducted a subgroup analysis comparing horses that did not develop diarrhea with horses that had diarrhea that lasted longer than 2 days, was associated with isolation of *Salmonella* spp from a fecal sample, or was leukopenic at the time of onset of diarrhea. Inclusion of horses in the subgroup, which

were found to be shedding *Salmonella* spp in their feces or were leukopenic at the time of onset of diarrhea, could be questioned because the number of horses with diarrhea that were tested for these conditions was small. Additionally, none of the horses without diarrhea was evaluated for evidence of *Salmonella* spp in feces or leukopenia and, therefore, might have been misclassified.

We included horses with diarrhea that had *Salmonella* spp isolated from their feces or that were leukopenic in the subgroup considered to have severe diarrhea because our clinical impression is that diarrhea associated with these findings can be severe. Horses shedding *Salmonella* spp were included in this subgroup because we believed the predictive value of a positive result for culture of these horses with diarrhea would be higher than that of a clinically healthy horse. Salmonellosis is considered the most common cause of acute infectious colitis with severe diarrhea in horses.<sup>11</sup> Gastrointestinal tract disease has been identified as an important risk factor for the development of salmonellosis in horses.<sup>12</sup> Additionally, horses with colitis may develop leukopenia.<sup>11,13</sup> Leukopenia develops in response to endotoxin or an inflammatory stimulus, which decreases the circulating pool of leukocytes (principally polymorphonuclear cells).<sup>13,14</sup> We believe that horses with diarrhea and a systemic response, reflected by leukopenia, are more severely affected with diarrhea than horses that do not have such a response. Results of analysis of the horses considered to have severe diarrhea were identical whether the subgroup was comprised only of horses with diarrhea that lasted longer than 2 days or included all horses with diarrhea that lasted longer than 2 days, had leukopenia, or had *Salmonella* spp isolated from fecal samples.

Surgery of the large intestine was associated with development of diarrhea in the horses of this study. Alterations in colonic flora, motility, vascular perfusion, or release of inflammatory mediators might have altered absorption or secretion by the colon.<sup>15</sup> Performing an enterotomy also was associated with development of diarrhea. Most (> 90%) of the enterotomies were performed at the pelvic flexure of the large colon. Diarrhea is a common sequela of evacuation of the large colon.<sup>8</sup> Intraluminal lavage of the colon with tap water may cause diarrhea by irritation of the colonic mucosa from use of a nonphysiologic solution, alterations in the colonic flora, and increased residual water content in the colon.<sup>8</sup> Enterotomy, however, was not associated with the subgroup of horses considered to have severe diarrhea, and may indicate that enterotomy is associated with the development of milder diarrhea only.

Results of analysis of the subgroup of horses considered to have severe diarrhea indicated that horses fed grass hay were about half as likely to develop diarrhea as horses not fed grass hay. The clinical importance of the apparent protective effect of grass hay is unclear. The association with grass hay was not confounded by the site of the surgical lesion (large intestine vs other) or any other variables examined in this study. The association may have resulted from another

management variable (eg, change in diet)<sup>16</sup> or another variable associated with colitis (eg, administration of phenylbutazone)<sup>15</sup> not examined in our analysis for which grass hay could be a proxy.

Seemingly, horses fed grass hay were at less risk of developing diarrhea. Grass hays generally contain more fiber than leguminous hays. Increased dietary fiber may have provided a protective effect by providing energy for colonocytes, stimulating segmental contractions, and increasing the bulk and form of feces.<sup>17</sup>

Unfortunately, none of the risk factors identified for the development of diarrhea after surgery in this study was alterable. Identification of horses at increased risk for the development of diarrhea, however, may enable clinicians to better advise clients and to better prepare for management after surgery. Because the type of hay fed may vary by region, extrapolation of results obtained from our clinic to populations of horses from other areas should be made with caution. Because 98% of horses included in the study received antibiotics, we could not examine the effects of antibiotic administration on the incidence of diarrhea.

## References

1. White NA. Intensive care, monitoring, and complications of acute abdominal disease. In: White NA, ed. *The equine acute abdomen*. Philadelphia: Lea & Febiger, 1990;310-335.
2. Hunt JM, Edwards GB, Clarke KW. Incidence, diagnosis, and treatment of postoperative complications in colic cases. *Equine Vet J* 1986;18:264-270.
3. Baxter GM, Broome TE, Moore JN. Abdominal adhesions after small intestinal surgery in the horse. *Vet Surg* 1989;18:409-414.
4. Pascoe PJ, McDonnell WN, Trim CM, et al. Mortality rates and associated factors in equine colic operations—a retrospective study of 341 operations. *Can Vet J* 1983;24:76-85.
5. McIlwraith CW. The acute abdominal patient: postoperative management and complications. *Vet Clin North Am Equine Pract* 1982;4:167-184.
6. Ducharme NG, Hackett RP, Ducharme GR, et al. Surgical treatment of colic: results in 181 horses. *Vet Surg* 1983;12:206-209.
7. Parry BW. Survey of 79 referral colic cases. *Equine Vet J* 1983;15:345-348.
8. Markel MD, Stover SM, Pascoe JR, et al. Evacuation of the large colon in horses. *Compend Contin Educ Pract Vet* 1988;10:96-102.
9. Rosner B. *Fundamentals of biostatistics*. 2nd ed. Boston: Duxbury Press, 1986;75-83, 302-346, 278-293.
10. Hosmer DW, Lemeshow S. *Applied logistic regression*. New York: John Wiley & Sons, 1989;135-173.
11. Smith BP. *Salmonella* infection in horses. *Compend Contin Educ Pract Vet* 1981;3:S4-S13.
12. Hird DW, Casebolt DB, Carter JD, et al. Risk factors for salmonellosis in hospitalized horses. *J Am Vet Med Assoc* 1986;188:173-177.
13. Whitlock RH. Colitis: differential diagnosis and treatment. *Equine Vet J* 1986;18:278-283.
14. Morris DD. Endotoxemia in horses: a review of cellular and humoral mediators involved in its pathogenesis. *J Vet Intern Med* 1991;5:167-178.
15. Murray MJ. Digestive physiology of the large intestine in adult horses. II. Pathophysiology of colitis. *Compend Contin Educ Pract Vet* 1988;10:1309-1315.
16. Traub-Dargatz JL, Salman MD, Jones RL. Epidemiologic study of salmonellae shedding in the feces of horses and potential risk factors for development of the infection in hospitalized horses. *J Am Vet Med Assoc* 1990;196:1617-1622.
17. Lewis LD. *Equine clinical nutrition*. Baltimore: The Williams & Wilkins Co, 1995;91-99, 408.