

Risk factors associated with fecal *Salmonella* shedding among hospitalized horses with signs of gastrointestinal tract disease

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Objective—To estimate prevalence of and identify risk factors for fecal *Salmonella* shedding among hospitalized horses with signs of gastrointestinal tract disease.

Design—Cross-sectional study.

Animals—465 hospitalized horses with gastrointestinal tract disease.

Procedure—Horses were classified as positive or negative for fecal *Salmonella* shedding during hospitalization by means of standard aerobic bacteriologic methods. The relationship between investigated exposure factors and fecal *Salmonella* shedding was examined by means of logistic regression.

Results—The overall prevalence of fecal *Salmonella* shedding was 13%. *Salmonella* serotype Newport was the most commonly isolated serotype (12/60 [20%]), followed by Anatum (8/60 [13%]), Java (13%), and Saint-paul (13%). Foals with gastrointestinal tract disease were 3.27 times as likely to be shedding *Salmonella* organisms as were adult horses with gastrointestinal tract disease. Adult horses that had been treated with antimicrobial drugs prior to hospitalization were 3.09 times as likely to be shedding *Salmonella* organisms as were adult horses that had not been treated with antimicrobial drugs prior to hospitalization. Adult horses that underwent abdominal surgery were 2.09 times as likely to be shedding *Salmonella* organisms as were adult horses that did not undergo abdominal surgery.

Conclusions and Clinical Relevance—Results suggest that a history of exposure to antimicrobial drugs prior to hospitalization and abdominal surgery during hospitalization were associated with *Salmonella* shedding in adult horses with gastrointestinal tract disease. Foals with gastrointestinal tract disease were more likely to shed *Salmonella* organisms than were adult horses with gastrointestinal tract disease. (*J Am Vet Med Assoc* 2004;225:275–281)

Fecal shedding of *Salmonella* organisms by hospitalized horses is an important problem for large animal hospitals. Several reports^{1–3} describing the temporary closure of veterinary teaching hospitals because

of outbreaks of *Salmonella* infection in hospitalized horses have been published, and it seems likely that not all such outbreaks have been reported. Negative aspects of previous outbreaks of salmonellosis in veterinary teaching hospitals include the risk of zoonotic infection,² high fatality rate among affected horses,² loss of revenue,¹ cost of facility renovation,¹ and loss of teaching cases.

Because of the detrimental impacts of *Salmonella* outbreaks on the overall mission of veterinary teaching hospitals, several epidemiologic studies have been conducted to investigate risk factors associated with fecal *Salmonella* shedding among hospitalized horses.^{2–5} Lower respiratory tract disease,³ colic at the time of admission,^{4,5} long-distance transport,^{5,6} a change in diet while hospitalized,⁷ withholding of feed,^{8,9} use of common instruments such as nasogastric tubes and rectal thermometers,^{1,9,10} and antimicrobial administration^{4,8,11} have been identified as risk factors associated with recovery of *Salmonella* organisms from the feces of horses in several veterinary teaching hospitals in the United States. However, extrapolating risk factors from previous studies to a particular hospital situation is difficult because of differences in hospital facilities, personnel, infection control protocols, caseload, host immune status, virulence of *Salmonella* isolates, and weather conditions. These differences accentuate the importance of identifying risk factors predisposing patients to infection at individual hospitals so that effective infection control measures can be formulated, implemented, and evaluated.

From 1999 through 2001, > 3,000 equine patients were admitted annually to the University of Florida Veterinary Medical Teaching Hospital (UF-VMTH). This coincided with an increase in the number of horses with clinical signs of salmonellosis that, in turn, led to the formulation and implementation of an infectious disease control program based on a surveillance system for early detection of fecal *Salmonella* shedding in hospitalized horses. The purposes of the study reported here were to estimate the prevalence of fecal *Salmonella* shedding among hospitalized horses with signs of gastrointestinal tract disease and identify risk factors associated with fecal *Salmonella* shedding.

Materials and Methods

Study design—The study was designed as a cross-sectional study. All horses admitted to the UF-VMTH between January and December 2002 with signs of gastrointestinal tract disease were eligible for inclusion in the study. Hospital

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medical records and a mail questionnaire were used to obtain data of epidemiologic interest for each horse included in the study. The frequency of investigated exposure factors was compared between horses classified as *Salmonella* shedders and nonshedders.

Collection of fecal samples—Fecal samples were collected from horses included in the study by hospital technicians at the time of admission or within 12 hours after admission and submitted for bacterial culture for *Salmonella* spp. Thereafter, additional samples were collected every 48 hours (ie, Monday, Wednesday, and Friday) as part of the hospital's surveillance and infection control program until the patient was discharged from the hospital. Fecal samples that were collected after regular business hours were refrigerated at 4°C prior to submission. In some horses, additional fecal samples were collected (eg, every 12 to 24 hours) at the discretion of the attending clinician. If a foal was admitted to the hospital with its mare, fecal samples were collected from both the foal and mare. An infection control officer (NSE) was responsible for overseeing collection of fecal samples, microbiologic procedures, and collection of epidemiologic data throughout the study period.

Microbiologic procedures for detection of *Salmonella* organisms—Bacterial culture of fecal samples for detection of *Salmonella* organisms was performed at the UF-VMTH Clinical Microbiology Laboratory. For selective enrichment, 2 to 5 g of fresh feces was placed in 10 mL of selenite broth,^a and the broth was incubated at 37°C. The following day, the selenite broth was subcultured on Hektoen enteric agar plates.^b Plates were incubated at 37°C for 18 to 24 hours, and nonlactose-fermenting, H₂S-producing colonies were selected and isolated. These colonies were then inoculated on urea agar slants, and slants were incubated at 37°C for 18 to 24 hours. Identification of urease-negative organisms was established through use of a commercially available identification system.^c Serogroup of *Salmonella* isolates was determined by means of agglutination; polyvalent and group-specific (A-E) antisera^d were used. *Salmonella* isolates were tested for antimicrobial susceptibility by means of the minimal inhibitory concentration method with commercially prepared plates.^e Serotyping of *Salmonella* isolates was performed at the USDA National Veterinary Services Laboratories in Ames, Iowa.

Data collection—A structured questionnaire was developed for collection of epidemiologic data, including host factors; farm factors; clinical findings at the time of hospitalization; and clinical findings, procedures, and treatments during hospitalization. Data collected for each horse included admission date, age, breed, sex, primary use (ie, breeding, pleasure, racing, showing, or other), transport by commercial or private conveyance, and duration of transport from the farm to the hospital (hours). Farm factors included type of housing (ie, private farm, boarding farm, training center, or other), water source (ie, well, municipal water source, or natural waterway), number of horses on the farm, and presence of other animals (ie, cattle, dogs, cats, and mice). Clinical findings at the time of hospitalization included initial complaint (ie, colic, diarrhea, or other), previous treatment with antimicrobial or anti-inflammatory drugs, deworming history, previous diet, treatment by the referring veterinarian, diagnostic findings (ie, results of nasogastric intubation, rectal palpation, and abdominocentesis), and date of admission. Clinical findings, procedures, and treatments during hospitalization were summarized into 3 periods representing logical breakpoints in the course of treatment (≤ 6 hours of hospitalization, 6 to 72 hours, and > 72 hours). Information on results of CBCs (for each period, values that were the most abnormal were recorded), clinical procedures (nasogastric

intubation, IV catheterization, rectal palpation, and abdominocentesis), colic surgery (enterotomy or resection), anti-inflammatory treatments, sedatives administered, antimicrobial drug treatment, diet during hospitalization (ie, hay, pellets, or grain), discharge status, date of discharge, and duration of hospitalization (days) was recorded.

Statistical analyses—Prevalence of fecal *Salmonella* shedding was calculated by dividing the number of horses from which *Salmonella* organisms were recovered at least once during hospitalization by the number of horses included in the study. Prevalence of fecal *Salmonella* shedding in foals (ie, horses < 1 year old) was compared with prevalence in adult horses (horses ≥ 1 year old) by use of the χ^2 test. The number of fecal samples collected from foals was compared with the number of fecal samples collected from adult horses by use of the Mann-Whitney *U* test.

Logistic regression was used to analyze risk factors for fecal *Salmonella* shedding. Only horses that had been hospitalized for ≥ 48 hours were included in these analyses because medical records were incomplete for some horses that had been hospitalized for < 48 hours. For analysis of risk factors, horses were classified as shedders (ie, horses admitted for gastrointestinal tract disease that had been hospitalized for at least 48 hours and from which *Salmonella* organisms were recovered from fecal samples at least once during hospitalization) or nonshedders (ie, horses admitted for gastrointestinal tract disease that had been hospitalized for at least 48 hours and from which *Salmonella* organisms were never isolated from fecal samples collected during hospitalization).

Univariable logistic regression was used for initial screening of potential risk factors for fecal *Salmonella* shedding. Continuous variables (eg, age, transport time, and the number of horses on the farm) were categorized into 2 or 4 groups on the basis of their frequency distributions (ie, median or quartiles). For variables with > 2 categories, adjacent categories were collapsed whenever it was biologically reasonable and when adjacent categories had similar stratum-specific odds for fecal *Salmonella* shedding (eg, age). One multivariable logistic regression model was used to identify potential risk factors associated with fecal *Salmonella* shedding in foals, and another model was used to identify potential risk factors in adult horses. For each model, all potential risk factors with *P* values ≤ 0.20 were entered in the starting model. Variables entered in the starting model were grouped into 3 subsets for further analysis (host and environmental factors, clinical signs, and antimicrobial drug treatment). A backward stepping approach was used to identify multivariable models for each subset, with a critical *P* value for retention of $P \leq 0.10$. Variables retained in the 3 subset multivariable models were then included in a single model, and backward elimination was used to identify a final multivariable model, with a critical *P* value for retention of $P \leq 0.10$. Season (winter vs summer), duration of hospitalization (days), and number of fecal samples collected and submitted for bacterial culture for *Salmonella* organisms (1, 2, 3, ≥ 4) were included as required variables in the final model because they can influence the probability of detecting *Salmonella* organisms. A model with a hierarchical structure was specified by adding terms for biologically plausible interactions between independent variables. A backward model selection procedure was used in a sequential fashion, starting with a full model. The model's goodness-of-fit was determined by calculation of the Hosmer-Lemeshow goodness-of-fit χ^2 statistic. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were determined from the final model. Duration of hospitalization (days) and number of fecal samples collected and submitted for bacterial culture were compared between horses classified as shedders and horses classified as nonshedders by means of the Mann-Whitney *U* test.

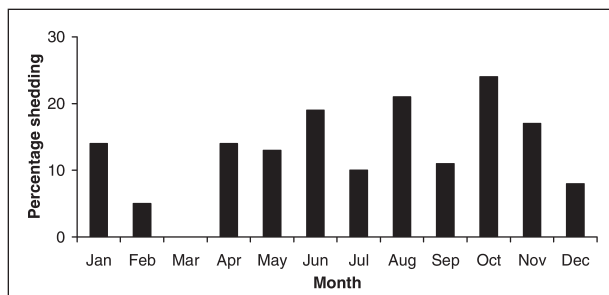


Figure 1—Monthly frequency of fecal shedding of *Salmonella* organisms among horses (n = 465) admitted to the University of Florida Veterinary Medical Teaching Hospital during 2002 because of signs of gastrointestinal tract disease.

Table 1—Results of univariable analysis of risk factors potentially associated with fecal shedding of *Salmonella* organisms among foals < 1 year old admitted to a veterinary teaching hospital because of signs of gastrointestinal tract disease.

Variable	No. of shedders (%)	No. of nonshedders (%)	P value
Age (d)			0.03
1 to 38	5 (29)	23 (61)	
> 38	12 (71)	15 (39)	
Sex			0.02
Female	4 (24)	22 (58)	
Male	13 (76)	16 (42)	
No. of horses on premises			0.02
1 to 25	5 (29)	18 (47)	
> 25	12 (71)	10 (26)	
Not determined	0 (0)	10 (26)	
Abdominal surgery			0.16
No	14 (82)	36 (95)	
Yes	3 (18)	2 (5)	
Mucous membranes (0 to 6 h after admission)			0.11
Normal	11 (65)	32 (84)	
Abnormal	6 (35)	6 (16)	
Leukopenia (6 to 72 h after admission)			0.17
No	3 (18)	11 (29)	
Yes	4 (24)	4 (11)	
Not determined	10 (59)	23 (61)	
Sedatives (6 to 72 h after admission)			0.15
Not used	12 (71)	33 (87)	
Used	5 (29)	5 (12)	
Band neutrophils (6 to 72 h after admission)			0.10
No	1 (6)	8 (21)	
Yes	6 (35)	7 (18)	
Not determined	10 (59)	23 (61)	
Season			0.08
Winter	3 (18)	16 (42)	
Summer	14 (82)	22 (58)	
Duration of hospitalization (d)			0.05
1 to 6	6 (35)	24 (63)	
> 6	11 (65)	14 (37)	
No. of fecal samples			0.02
1	1 (6)	13 (34)	
2	4 (23)	8 (21)	
3	1 (6)	7 (18)	
≥ 4	11 (65)	10 (26)	

Only those variables for which the P value was ≤ 0.20 are shown. Horses were classified as shedders if they had been admitted because of gastrointestinal tract disease and hospitalized for at least 48 hours and *Salmonella* organisms were recovered from at least 1 fecal sample collected during hospitalization. Horses were classified as nonshedders if they had been admitted because of gastrointestinal tract disease and hospitalized for at least 48 hours and *Salmonella* organisms had never been isolated from fecal samples collected during hospitalization.

Results

During the study period, 1,750 equine patients were hospitalized at the UF-VMTH. Of these, 465 (27%) were admitted because of signs of gastrointestinal tract disease and were included in the study. Information for all 465 of these horses was used to determine prevalence of fecal *Salmonella* shedding. One hundred two of the 465 were hospitalized for < 48 hours, and information from the remaining 363 horses was used to analyze potential risk factors for fecal *Salmonella* shedding.

Overall prevalence of fecal *Salmonella* shedding was 13% (60/465). Monthly prevalence ranged from 0% in March to 24% in October (Figure 1). Prevalence of shedding was significantly ($P < 0.01$) higher in foals (23/87 [26%]) than in adult horses (37/378 [9.7%]). However, the number of fecal samples collected from foals (median, 3; range, 1 to 11) was not significantly different ($P = 0.42$) than the number collected from adult horses (median, 3; range, 1 to 18). *Salmonella* serotype Newport was the most commonly isolated serotype (12/60 [20%]), followed by Anatum (8/60 [13%]), Java (8/60 [13%]), and Saint-paul (8/60 [13%]). Median time from admission to identification of fecal *Salmonella* shedding was 3.5 days (range, 2 to 10 days) for horses infected with *Salmonella* serotype Java, 2 days (range, 0 to 6 days) for horses infected with *Salmonella* serotype Newport, 1.5 days (range, 0 to 4 days) for horses infected with *Salmonella* serotype Anatum, and 1 day (range, 0 to 4 days) for horses infected with *Salmonella* serotype Saint-paul. Examination of antimicrobial susceptibility patterns and spatial and temporal distribution of *Salmonella* isolates suggested that most (5/8) *Salmonella* serotype Java infections during the study period were likely of nosocomial origin.

Of the 363 horses hospitalized for ≥ 48 hours, 54 (17 foals and 37 adult horses) were classified as shedders and 309 (38 foals and 271 adult horses) were classified as nonshedders. Foals with gastrointestinal tract disease were significantly ($P < 0.01$) more likely to be shedding *Salmonella* organisms in their feces than were adult horses with gastrointestinal tract disease (OR, 3.27; 95% CI, 1.68 to 6.38). Analyses of potential risk

Table 2—Results of multivariable analysis of potential risk factors for fecal shedding of *Salmonella* organisms among foals admitted to a veterinary teaching hospital because of signs of gastrointestinal tract disease.

Variable	Adjusted OR	95% CI	P value
Age (d)			
1 to 38	Reference	NA	NA
> 38	5.55	1.08–28.55	0.04
Season			
Winter	Reference	NA	NA
Summer	5.12	0.93–28.29	0.06
Duration of hospitalization (d)			
2 to 5	Reference	NA	NA
> 5	3.86	0.57–26.29	0.16
No. of fecal samples			
1	Reference	NA	NA
2	4.90	0.39–61.06	0.21
3	0.40	0.01–13.24	0.60
≥ 4	2.95	0.19–46.53	0.44

OR = Odds ratio. CI = Confidence interval. NA = Not applicable.

Table 3—Results of univariable analysis of risk factors potentially associated with fecal shedding of *Salmonella* organisms among adult horses (> 1 year old) admitted to a veterinary teaching hospital because of signs of gastrointestinal tract disease.

Variable	No. of shedders (%)	No. of nonshedders (%)	P value
Transport by commercial van			0.20
No	27 (73)	221 (82)	
Yes	10 (27)	49 (18)	
Travel time (h)			0.09
0 to 1.5	17 (46)	164 (61)	
> 1.5	20 (54)	107 (39)	
No. of horses at the farm			0.05
0 to 11	22 (59)	112 (41)	
> 11	11 (30)	119 (44)	
Not determined	4 (11)	40 (15)	
How grain and pellets fed			0.01
Bucket	14 (38)	163 (60)	
Feeder	20 (54)	103 (38)	
Not determined	3 (8)	5 (2)	
Cattle at the farm			0.12
No	26 (70)	220 (81)	
Yes	11 (30)	51 (19)	
Previous exposure to antimicrobial drugs			0.04
No	32 (86)	258 (95)	
Yes	5 (14)	13 (5)	
Abdominal surgery			0.03
No	22 (59)	206 (76)	
Yes	15 (41)	65 (24)	
Mucous membranes (0 to 6 h after admission)			0.01
Normal	14 (38)	161 (59)	
Abnormal	22 (59)	108 (40)	
Not determined	1 (3)	2 (1)	
Antimicrobial drugs (0 to 6 h after admission)			< 0.01
No	18 (49)	213 (79)	
Yes	19 (51)	58 (21)	
Potassium penicillin (0 to 6 h after admission)			< 0.01
No	21 (57)	228 (84)	
Yes	16 (43)	43 (16)	
Metronidazole (0 to 6 h after admission)			0.17
No	33 (89)	257 (95)	
Yes	4 (11)	14 (5)	
Leukopenia (0 to 6 h after admission)			0.18
No	22 (59)	180 (66)	
Yes	8 (22)	36 (13)	
Not determined	7 (19)	55 (20)	
Neutropenia (0 to 6 h after admission)			0.03
No	23 (62)	168 (62)	
Yes	6 (16)	17 (6)	
Not determined	8 (22)	86 (32)	
Fibrinogen (0 to 6 h after admission)			0.12
0 to 400 mg/dL	19 (51)	164 (61)	
> 400 mg/dL	11 (30)	51 (19)	
Not determined	7 (19)	56 (21)	
Fever (6 to 72 h after admission)			0.06
No	8 (22)	102 (38)	
Yes	27 (73)	157 (58)	
Not determined	2 (5)	12 (4)	

Variable	No. of shedders (%)	No. of nonshedders (%)	P value
Anti-inflammatory drugs (6 to 72 h after admission)			0.02
Yes	28 (76)	153 (56)	
No	9 (24)	118 (44)	
Antimicrobial drugs (6 to 72 h after admission)			< 0.01
No	11 (30)	167 (62)	
Yes	26 (70)	104 (38)	
Potassium penicillin (6 to 72 h after admission)			< 0.01
No	14 (38)	167 (62)	
Yes	23 (62)	89 (33)	
Not determined	0 (0)	15 (6)	
Metronidazole (6 to 72 h after admission)			< 0.01
No	26 (70)	238 (88)	
Yes	11 (30)	33 (12)	
Band neutrophils (6 to 72 h after admission)			0.12
No	1 (3)	17 (6)	
Yes	11 (30)	36 (13)	
Not determined	25 (67)	218 (80)	
Fibrinogen (6 to 72 h after admission)			0.07
0 to 400 mg/dL	2 (5)	27 (10)	
> 400 mg/dL	9 (24)	27 (10)	
Not determined	26 (70)	217 (80)	
Fever (> 72 h after admission)			0.09
No	7 (19)	65 (24)	
Yes	21 (57)	90 (33)	
Not determined	9 (24)	116 (43)	
Antimicrobial drugs (> 72 h after admission)			0.05
No	13 (35)	115 (42)	
Yes	19 (51)	79 (29)	
Not determined	5 (14)	77 (28)	
Potassium penicillin (> 72 h after admission)			0.19
No	19 (51)	131 (48)	
Yes	13 (35)	54 (20)	
Not determined	5 (14)	86 (32)	
Pellets during hospitalization			0.01
No	16 (43)	173 (64)	
Yes	21 (57)	98 (36)	
Season			0.69
Winter	18 (49)	141 (52)	
Summer	19 (51)	130 (48)	
Duration of hospitalization (d)			0.05
1 to 5	15 (41)	156 (58)	
> 5	22 (59)	115 (42)	
No. of fecal samples			< 0.01
1	6 (16)	62 (23)	
2	5 (14)	78 (29)	
3	5 (14)	56 (21)	
≥ 4	21 (56)	75 (27)	

See Table 1 for key.

factors were conducted independently for foals and adult horses because foals had higher odds of fecal *Salmonella* shedding and are typically managed differently at the farm of origin and during hospitalization than adult horses.

Risk factors for *Salmonella* shedding in foals with gastrointestinal tract disease—Mean \pm SD age of the 55 foals was 75 ± 79 days (median, 38 days; range, 1 to 250 days). Twenty-six (47%) were females, and 29 (53%) were males. Ten breeds were represented,

including Thoroughbred (30 [55%]), Quarter Horse (6 [11%]), and Arabian (5 [9%]). Six (3 classified as shedders, and 3 classified as nonshedders) of the 55 (11%) foals died or were euthanatized without being discharged from the hospital. Ten of the 17 (59%) foals classified as shedders and 26 of the 38 (68%) foals classified as nonshedders were hospitalized with their mares. Two mares that were admitted with foals classified as shedders were also found to be shedding *Salmonella* organisms in their feces. Duration of hospitalization was significantly ($P = 0.01$) longer for foals classified as shedders (median, 9 days; range, 3 to 23

days) than for foals classified as nonshedders (median, 6 days; range, 3 to 21 days). Median number of fecal samples collected and submitted for bacterial culture for *Salmonella* organisms was significantly ($P < 0.01$) higher for foals classified as shedders (median, 5; range, 1 to 11) than for foals classified as nonshedders (median, 2; range, 1 to 7).

Eleven of the 21 variables examined in univariable analyses had P values ≤ 0.20 (Table 1) and were included in the multivariable analysis. Season, duration of hospitalization, and number of fecal samples were forced into the final model because they can influence the probability of detecting *Salmonella* organisms. The only other variable that was retained in the final model was age (Table 2). Addition of 2-way interaction terms did not contribute to the final model, and these terms were removed. Foals > 38 days old were significantly ($P = 0.04$) more likely to shed *Salmonella* organisms in their feces, compared with foals ≤ 38 days old (OR, 5.55; 95% CI, 1.08 to 28.55). The P value for goodness-of-fit of the final model was 0.81, indicating overall good fit.

Risk factors for *Salmonella* shedding among adult horses with gastrointestinal tract disease—Mean \pm SD age of the 308 adult horses was 9 ± 6 years (median, 7 years; range, 1 to 31 years). One hundred forty-six (47%) were females, 82 (27%) were geldings, and 80 (26%) were sexually intact males. Twenty-three breeds were represented, including Thoroughbred (89 [29%]), Quarter Horse (80 [26%]), Arabian (25 [8%]), and American Paint Horse (22 [7%]). Twenty-seven (2 classified as shedders, and 25 classified as nonshedders) of the 308 (9%) adult horses died or were euthanized without being discharged from the hospital. Duration of hospitalization was significantly ($P = 0.01$) longer for horses classified as shedders (median, 6 days; range, 2 to 19 days) than for horses classified as nonshedders (median, 5 days; range, 2 to 41). Median number of fecal samples collected and submitted for bacterial culture for *Salmonella* organisms was significantly ($P < 0.01$) higher for horses classified as shedders (median, 4; range, 1 to 8) than for horses classified as nonshedders (median, 2; range, 1 to 18).

Twenty-eight of the 89 variables examined in univariable analyses had P values ≤ 0.20 (Table 3) and were included in the multivariable analysis. Season, duration of hospitalization, and number of fecal samples were forced into the final model. The only other variables that were retained in the final model were previous exposure to antimicrobial drugs and abdominal surgery (Table 4). Addition of 2-way interaction terms did not contribute to the final model, and these terms were removed. Horses exposed to antimicrobial drugs prior to hospitalization were more likely to shed *Salmonella* organisms in their feces than horses without such exposure (OR, 3.09; 95% CI, 0.94 to 10.14; $P = 0.06$), and horses that underwent abdominal surgery were more likely to shed *Salmonella* organisms in their feces than horses that did not undergo abdominal surgery (OR, 2.09; 95% CI, 0.93 to 4.71; $P = 0.07$). The P value for goodness-of-fit of the final model was 0.91, indicating overall good fit.

Table 4—Results of multivariable analysis of potential risk factors for fecal shedding of *Salmonella* organisms among adult horses admitted to a veterinary teaching hospital because of signs of gastrointestinal tract disease.

Variable	Adjusted OR	95% CI	P value
Previous exposure to antimicrobial drugs			
No	Reference	NA	NA
Yes	3.09	0.94–10.14	0.06
Abdominal surgery			
No	Reference	NA	NA
Yes	2.09	0.93–4.71	0.07
Season			
Winter	Reference	NA	NA
Summer	1.14	0.56–2.32	0.72
Duration of hospitalization (d)			
2 to 5	Reference	NA	NA
> 5	0.65	0.22–1.96	0.44
No. of fecal samples			
1	Reference	NA	NA
2	0.58	0.17–2.02	0.38
3	0.96	0.26–3.59	0.95
≥ 4	2.99	0.81–11.01	0.09

See Table 2 for key.

Discussion

In the present study, fecal *Salmonella* shedding was detected at least once in 60 of 465 (13%) horses hospitalized because of gastrointestinal tract disease. Detection of horses shedding *Salmonella* organisms is important because these horses represent a potential source for nosocomial infection. At the UF-VMTH, detection of fecal *Salmonella* shedding in hospitalized horses triggers an immediate response involving implementation of infection control measures, including gloves, gowns, plastic boots, mats with disinfectant, and a rope barricade around the stall door. If a horse develops diarrhea, it is segregated from the hospitalized population and placed in isolation in a separate facility.

Various estimates of the prevalence of fecal *Salmonella* shedding in hospitalized horses with gastrointestinal tract disease have been reported.^{5,8,11,12} However, results from previous studies are difficult to compare with results of the present study because of differences in the number of study animals, number of fecal samples tested per animal, and frequency distribution of risk factors associated with *Salmonella* shedding. The overall prevalence of fecal *Salmonella* shedding (13%) in the present study was similar to that reported in a previous study¹² involving 100 horses admitted to a hospital in Pennsylvania because of colic, but it was higher than prevalences reported in studies in Colorado⁵ (23/246 [9%]) and California^{8,11} (78/1,429 [5%] and 46/1,451 [3%]). Importantly, only those horses admitted to the UF-VMTH because of signs of gastrointestinal tract disease were included in the present study, as they were part of the hospital's surveillance program for early detection of fecal *Salmonella* shedding during hospitalization. Thus, the prevalence estimate in the present study is not representative of values expected for all horses admitted to the hospital.

In the present study, season was included in analyses of potential risk factors for fecal *Salmonella* shedding because it has been associated with incidence of salmonellosis in hospitalized horses in previous studies in Michigan (higher prevalence in summer)² and

California (higher prevalence in fall)⁸ and because the summer months (May through September) are associated with a high caseload at the UF-VMTH, which can be an important contributor to the spread of nosocomial disease.⁵ In addition, because duration of hospitalization can serve as a marker of disease severity⁵ and horses with more severe disease are more likely to shed *Salmonella* organisms⁵ and because duration of hospitalization had an effect on the number of fecal samples submitted for bacterial culture, which could have affected the probability of detecting *Salmonella* organisms,^{5,12,13} both duration of hospitalization and number of fecal samples were retained in the final logistic regression models. Results of the present study suggest that foals were more likely to shed *Salmonella* organisms in their feces than adult horses. In addition, adult horses with a history of exposure to antimicrobial drugs prior to hospitalization and horses that underwent abdominal surgery were more likely to shed *Salmonella* organisms, compared with horses without a history of exposure to antimicrobial drugs and horses that did not undergo abdominal surgery, respectively.

Four factors could account for the higher prevalence of fecal *Salmonella* shedding among foals, compared with adult horses. First, foals are known to be susceptible to colonization with *Salmonella* organisms soon after parturition because of a lack of microflora that may provide protection against establishment, proliferation, and infection of the gastrointestinal tract.^{14,15} Second, foals tend to be immunoincompetent at birth, depending on maternal immunoglobulins for protection against infectious agents.^{14,15} Third, as a result of the stress of parturition, carrier mares can begin shedding organisms, becoming an important source of contamination for foals and their environment.¹⁵ Fourth, coprophagia is a normal behavior in foals during the first or second month after birth.¹⁶

In the present study, foals with gastrointestinal tract disease that were > 38 days old were more likely to shed *Salmonella* organisms in their feces than were younger foals. The reason for this was not apparent; however, it may reflect exposure to *Salmonella* organisms in contaminated feed, hay, or bedding. Overall, the fact that foals with gastrointestinal tract disease were more likely to shed *Salmonella* organisms in their feces than were adult horses suggests that infection control measures should be used for this subpopulation of foals from the time of admission to the hospital to prevent cross-infection and environmental contamination. In the past, infection control methods were not used for such foals admitted to the UF-VMTH unless they had clinical signs of salmonellosis (ie, diarrhea, fever, and leukopenia) at the time of admission or developed such signs while hospitalized.

Adult horses with gastrointestinal tract disease in the present study that had been exposed to antimicrobial drugs prior to hospitalization were more likely to shed *Salmonella* organisms than were adult horses without such exposure. An association between antimicrobial drug treatment and *Salmonella* infection in hospitalized horses has been identified in previous studies.^{4,8,17} The normal intestinal microflora is considered an important line of defense against colonization

by pathogenic bacteria, and the association between exposure to antimicrobial drugs and *Salmonella* shedding could be explained by selective elimination of intestinal microflora antagonistic to *Salmonella* organisms.^{9,11} Treatment with potassium penicillin¹¹ or oxytetracycline¹⁷ has been identified as a risk factor for *Salmonella* shedding in hospitalized horses.

Finally, in the present study, adult horses with gastrointestinal tract disease that underwent abdominal surgery were more likely to shed *Salmonella* organisms than were adult horses that did not undergo abdominal surgery. Surgery, particularly abdominal surgery, has previously been suggested to be a risk factor for *Salmonella* shedding in horses.^{6,8,18,19} Horses with gastrointestinal tract disease that undergo abdominal surgery suffer substantial amounts of stress. In addition, the large colon or cecum may be emptied and lavaged, feed may be withheld, antimicrobial and anesthetic drugs may be administered, and various degrees of ileus may develop.⁸ These events are likely to alter the intestinal tract microflora.⁸ In a study⁶ involving experimental challenge with *Salmonella* serotype Typhimurium, stress induced by transportation, withholding of feed, antimicrobial drug administration, or surgery exacerbated the severity of clinical disease and increased *Salmonella* shedding in 12 of 17 ponies. Yet, abdominal surgery was not identified as an important risk factor associated with *Salmonella* shedding in epidemiologic studies in California^{4,9,11} and Colorado.^{5,7} The studies^{4,9,11} in California, however, identified the use of antimicrobial drugs after surgery as an important risk factor for *Salmonella* shedding. It is possible that abdominal surgery and exposure to antimicrobial drugs after surgery may interact with each other to affect the probability of *Salmonella* shedding, but the sample size was too low in the present study to adequately assess such an interaction.

^aSelenite broth, Hardy Diagnostics, Santa Maria, Calif.

^bHektoen enteric agar, Hardy Diagnostics, Santa Maria, Calif.

^cAPI-20E system, bioMérieux Sa, Marcy l'Etoile, France.

^dBacto-Salmonella antisera, DIFCO Laboratories, Detroit, Mich.

^eSensititre, Radiometer America, Westlake, Ohio.

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