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Using Syndromic Surveillance to Estimate Baseline Rates for Healthcare-Associated Infections in Critical Care Units of Small Animal Referral Hospitals

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Background: Expected rates of healthcare-associated infections (HCAI) have not been established in veterinary hospitals. Baseline rates are critically needed as benchmarks for quality animal care.

Objective: To estimate the occurrence of events related to HCAI identified using a standardized syndromic surveillance system in small animals in critical care cases at referral hospitals.

Animals: Weaned dogs and cats (n = 1,951) that were hospitalized in the critical care unit of referral teaching hospitals during a 12-week period.

Methods: Multicenter, prospective longitudinal study. A survey was completed for all enrolled animals to record basic demographics, information about procedures and treatments that animals received, and to document the occurrence of defined nosocomial syndromes. Data were analyzed to identify risk factors associated with the occurrence of these nosocomial syndromes.

Results: Controlling for hospital of admission, 16.3% of dogs (95% confidence intervals [CI], 14.3–18.5) and 12% of cats (95% CI, 9.3–15.5) were reported to have had ≥1 nosocomial syndrome occur during hospitalization. Risk factors found to have a positive association with the development of a nosocomial syndrome were longer hospital stays, placement of a urinary catheter, surgical procedures being performed, and the administration of antiulcer medications and antimicrobial drugs excluding those given perioperatively.

Conclusions and Clinical Importance: Syndromic surveillance systems can be successfully standardized for use across multiple hospitals to effectively collect data pertinent to HCAI rates and risk factors for occurrence.

Key words: Adverse outcomes; Hospital-acquired infection; Nosocomial infection; Preventable fraction; Zoonosis.

Expected rates for healthcare-associated infections (HCAI) have not been well established for veterinary hospitals, but are clearly an important concern because of their negative impact on the quality of animal care.[1–7] According to a survey of 38 veterinary teaching hospitals at American Veterinary Medical Association accredited veterinary colleges, 82% of respondent hospitals (31/38) recognized outbreaks of HCAI in the 5 years before interviews, and 50% of hospitals identified zoonotic infections among personnel in the previous 2 years.[8] Because baseline rates of HCAI have not been established, it is unknown how many of these infections are preventable. Without this information, it is difficult to efficiently target areas for corrective action in hospital infection control practices to optimize the quality of care.

Abbreviations:

AVMA	American Veterinary Medical Association
CDC	Centers for Disease Control and Prevention
HCAI	healthcare-associated infections

Surveillance for HCAI provides a foundation for infection control programs and allows for endemic rates of infection to be determined.[9–11] Focusing surveillance efforts on animals with higher risks of developing HCAI increases the efficiency and cost-effectiveness of surveillance systems, regardless of whether increased risk is related to the type or severity of disease, the types of medical interventions that are being used, or because animals are being cared for in areas where there is an increased likelihood of exposure to contagious diseases.[6,9,12] Surveillance for HCAI allows for the detection of changes in the rate or the distribution of HCAI, which can lead to the identification of contagious disease threats.[9,10]

Syndromic surveillance involves the measurement of nonspecific indicators of health or disease (such as monitoring sales of over the counter medications) rather than monitoring more specific measures of disease occurrence (such as results of laboratory tests used to identify microorganisms in biological specimens). For veterinary hospitals, syndromic surveillance systems could be used to detect the rates of definable health events by tracking groups of disease signs based on recognition of clinical signs (eg, inflammation) or organ

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system involvement (eg, gastrointestinal tract disorders). Tracking the occurrence of syndromic indicators of disease is potentially less costly and more widely applicable than using surveillance systems that rely on laboratory diagnoses and have been applied in both human and, limitedly, in veterinary medicine.[6,13–17] Additionally, because syndromic surveillance systems can use clinical observation, the detection of abnormalities in disease trends is likely to be more rapid than systems that use information from laboratory or other confirmatory tests because of the inherent lag time associated with the latter.[13,15,16]

To most effectively optimize infection control practices, baseline or expected rates of infection must be established to target areas requiring improvement and to detect temporal changes.[6,15] However, there can be inherent differences in risks for HCAI in different animal populations and environments, and it is therefore important that baseline rates are estimated in multiple healthcare settings rather than a single hospital. The purpose of this study was to perform a multicenter evaluation of a standardized syndromic surveillance system to estimate rates of HCAI among critically ill dogs and cats.

Materials and Methods

Case Selection

A prospective longitudinal design was used for this study. Dogs and cats admitted to 4 participating veterinary referral hospitals (James L. Voss Veterinary Teaching Hospital at Colorado State University, Tufts New England Veterinary Medical Center, University of Minnesota Veterinary Medical Center, or the Veterinary Medical Teaching Hospital at the University of Missouri) during a 12-week period in 2006 were eligible for enrollment in the study. The study was restricted to weaned animals that were hospitalized for ≥1 day in the critical care unit. This population of animals was selected because they were considered likely to have an elevated risk of occurrence of HCAI.[11,18]

Data Collection

A form was constructed to standardize data collection for each eligible animal.[a] Three types of information were collected: demographic information, procedures and treatments performed during hospitalization, and the occurrence of ≥1 defined nosocomial syndromes. The exposures and syndromes included on the form were identified in a way that the form could be applied to all animal species, not just dogs and cats. This was carried out to allow comparison of event rates among different service areas within a hospital as well as between different facilities. At the time of animal admission to the hospital, an infection control technician or the primary clinician for each eligible case was given a form to complete. The form became part of the animal's hospital record and staff were encouraged to complete the form throughout hospitalization. The form was checked for completeness after the dog or cat was discharged. Project coordinators at participating centers followed up with the responsible clinicians if forms were incomplete.

The demographic information collected for each animal included: unique hospital identification, species (dog or cat), age, and sex and sex status (female, spayed female, male, or castrated male), the admitting hospital service, and the duration of hospitalization. The clinicians were asked to report if any of the following procedures or treatments had been performed or given at any time during hospitalization: placement of an intravenous or urinary catheter, any type of surgical procedure, implantation of devices at the time of surgery, endotracheal intubation, respiratory endoscopy, gastrointestinal endoscopy, perioperative antimicrobial drugs, antimicrobial drugs given at times other than perioperatively, antiulcer medications, and if specimens were submitted to the diagnostic laboratory to identify infectious agents (Table 1).

The 7 nosocomial syndromes investigated in this study were identified and defined by consensus among the authors. These included intravenous catheter site inflammation, urinary tract inflammation after urinary catheterization, acute infectious respiratory tract disorders, acute gastrointestinal disorders, surgery site inflammation or infection, fever of undetermined origin, and septicemia (Table 2). Because of the limited literature regarding definitions of HCAI in animals, many of these event definitions were modeled after the definitions published by the US Centers for Disease Control and Prevention for the reporting of HCAI in human healthcare facilities.[17] Clinicians were asked to report if any of the nosocomial syndromes occurred at any time after admission to the hospital, but only if the event was unrelated to the primary reason for hospitalization and not an expected outcome from a procedure that had been performed or treatment that had been given. For example, reported nosocomial syndromes would not include vomiting in a dog that had been admitted for acute pancreatitis. Clinicians were asked to report the occurrence of these events without presuming whether or not an event had an infectious etiology or was associated with significant morbidity in the animal.

Data Analysis

Information about animals was recorded on hard copy forms and responses were subsequently entered into an electronic database and validated through comparison to the electronic medical record for 25.7% (502) of the total animals enrolled in the study. Categorical variables were summarized using frequency distributions, and continuous variables were analyzed descriptively by calculating means, standard deviations, medians, 95% confidence intervals (CI), and ranges. Continuous variables were then categorized to facilitate inferential analysis. Data from dogs and cats were analyzed separately.

The frequency of occurrence of the nosocomial syndromes were estimated as incidence rates (numbers of affected animals per 100 hospital days) and attack rates (percentage of animals affected during the study period among the at-risk population). Because the occurrence of HCAI has been shown to differ among hospitals and because of the patient demographics and differences in exposure to risk factors, these estimates were adjusted to account for hospital of admission using Poisson regression.[19]

Random effects logistic regression (random slope and random intercept) was used to examine associations between potential risk factors (exposure variables) and the occurrence of nosocomial syndromes.[b,20] The primary outcome analyzed was the occurrence of ≥1 nosocomial syndrome in an animal. Factors related to the occurrence of each of the individual syndromes were also analyzed separately as secondary outcomes (Table 2). Potential exposure variables that were included in the analyses were placement of intravenous or urinary catheter, respiratory endoscopy, gastrointestinal endoscopy, endotracheal intubation, surgical procedures, placement of an implant at the time of surgery, antimicrobial drugs (either given perioperatively or at other times), the use of antiulcer medications, the animal's age and sex, the admitting hospital service, submission of samples for

Table 1. Characteristics of the dogs and cats enrolled in the study.

		Dog (n = 1,535)			Cat (n = 416)		
Characteristics	Category	Percent (n) of All Dogs	Percent (n) of Dogs with Any Reported Event (n = 298)	Percent (n) of Dogs with No Reported Nosocomial Event (n = 1,237)	Percent (n) of All Cats	Percent (n) of Cats with Any Reported Event (n = 67)	Percent (n) of Cats with No Reported Nosocomial Event (n = 349)
Age[a]	Less than 1 year	9.2 (144)	8.7 (26)	9.5 (118)	5.5 (23)	4.5 (3)	5.7 (20)
	1–5 years	33.9 (520)	33.2 (99)	34.0 (421)	30.5 (127)	37.3 (25)	29.2 (102)
	6–10 years	37.6 (577)	40.3 (120)	36.9 (457)	32.0 (133)	32.8 (22)	31.8 (111)
	11 years and older	19.2 (294)	17.8 (53)	19.5 (241)	32.0 (133)	25.4 (17)	33.2 (116)
Sex[b]	Female	9.0 (138)	9.1 (27)	9.0 (111)	7.0 (29)	6.0 (4)	7.2 (25)
	Female spayed	40.7 (625)	40.6 (121)	40.1 (504)	35.3 (147)	23.9 (16)	37.5 (131)
	Male	9.8 (151)	8.1 (24)	10.3 (127)	2.4 (10)	4.5 (3)	2.0 (7)
	Male castrated	40.3 (618)	42.3 (126)	39.8 (492)	55.1 (229)	65.7 (44)	53.0 (185)
Hospital of admission	A	23.7 (364)	20.1 (60)	24.6 (304)	15.1 (63)	11.9 (8)	15.8 (55)
	B	27.5 (422)	51.0 (152)	21.8 (270)	40.1 (167)	68.7 (46)	34.7 (121)
	C	27.9 (428)	20.1 (60)	29.8 (368)	17.8 (74)	4.5 (3)	20.3 (71)
	D	20.9 (321)	8.7 (26)	23.9 (295)	26.9 (112)	14.9 (10)	29.2 (102)
Duration of hospitalization	1 day	26.8 (411)	15.8 (47)	29.4 (364)	26.2 (109)	16.4 (11)	28.1 (98)
	2 days	28.1 (432)	21.1 (63)	29.8 (369)	26.2 (109)	20.9 (14)	27.2 (95)
	3 days	16.3 (250)	15.8 (47)	16.4 (203)	17.1 (71)	9.0 (6)	18.6 (65)
	4 days	9.1 (139)	10.4 (31)	8.7 (108)	9.9 (41)	11.9 (8)	9.5 (33)
	5 days	7.0 (108)	9.4 (28)	6.5 (80)	8.4 (35)	17.9 (12)	6.6 (23)
	6 or more days	12.7 (195)	27.5 (82)	9.1 (113)	12.3 (51)	23.9 (16)	10.0 (35)
Procedures and medications of interest[c]	Intravenous catheter	98.2 (1,508)	99.7 (297)	97.9 (1,211)	97.4 (405)	100 (67)	96.9 (338)
	Urinary catheter	18.2 (280)	32.2 (96)	14.9 (184)	17.1 (71)	40.3 (27)	12.6 (44)
	Surgical procedure	42.2 (647)	53.4 (159)	39.5 (488)	21.4 (89)	46.3 (31)	16.6 (58)
	Implant placed during surgery	11.3 (174)	9.4 (28)	11.8 (146)	5.5 (23)	11.9 (8)	4.3 (15)
	Endotracheal intubation	47.7 (732)	54.4 (162)	46.1 (570)	27.9 (116)	50.8 (34)	23.5 (82)
	Respiratory endoscopy	1.8 (28)	2.0 (6)	1.8 (22)	1.7 (7)	4.5 (3)	1.2 (4)
	Gastrointestinal endoscopy	1.8 (28)	2.0 (6)	1.8 (22)	1.7 (7)	3.0 (2)	1.4 (5)
	Perioperative antimicrobials	33.4 (512)	32.2 (96)	33.6 (416)	14.7 (61)	19.4 (13)	13.8 (48)
	Antimicrobials (not perioperative)	48.9 (750)	65.1 (194)	45.0 (556)	53.1 (221)	68.7 (46)	50.1 (175)
	Antiulcer medications	33.6 (515)	53.0 (158)	28.9 (357)	33.7 (140)	62.7 (42)	28.1 (98)
	Samples submitted for microbiology	22.5 (346)	38.6 (115)	18.7 (231)	28.6 (119)	41.8 (28)	26.1 (91)
	Agents recovered from sample submission	11.0 (169)	24.5 (73)	7.8 (96)	15.4 (64)	31.3 (21)	12.3 (43)
Patient admitted on an emergency basis	Yes	41.0 (630)	37.3 (111)	42.0 (519)	52.9 (220)	50.8 (34)	53.3 (186)
	No	59.0 (905)	62.8 (187)	58.0 (718)	47.1 (196)	49.3 (33)	46.7 (163)
Discharge Status	Alive	88.9 (1,365)	89.6 (267)	88.8 (1,098)	85.1 (354)	74.6 (50)	87.1 (304)
	Died/euthanized	11.1 (170)	10.4 (31)	11.2 (139)	14.9 (62)	25.4 (17)	12.9 (45)

[a]Three values missing from dogs with no reported events category.
[b]Three values missing from dogs with no reported event and 1 value missing from cats with no reported event categories.
[c]Not mutually exclusive categories.

microbiology, whether animals were admitted to the hospital on an emergency basis (regardless of the time of day when admitted), and the duration of hospitalization.

Univariable models were used to screen individual exposures. Variables that passed screening with a critical α of 0.25 were then included in multivariable model building using manual backward selection with a critical α for retention of 0.05. Two variables, placement of an intravenous catheter and the occurrence of any surgical procedure, were forced into models because of their dependencies with intravenous catheter site inflammation and

Table 2. Occurrence of nosocomial events after admission, adjusted to account for differences among hospitals.[a]

	Adjusted Risk (95% CI) for Events[b]			Adjusted Incidence (95% CI) of Events[c]		
Syndrome (Case Definition)	Dog	Cat	*P*-Value[d]	Dog	Cat	*P*-Value[d]
Any event	16.3 (14.3, 18.5)	12.0 (9.3, 15.5)	<.001	5.2 (4.6, 6.0)	3.7 (2.9, 4.8)	<.001
IV catheter site inflammation (abnormal inflammation of the skin, subcutaneous tissues, or blood vessels at sites where indwelling catheters were placed manifested by redness, swelling, heat, drainage, or thrombosis)	5.5 (4.4, 6.9)	4.0 (2.6, 6.2)	.15	1.8 (1.4, 2.2)	1.2 (0.8, 1.9)	.08
Urinary tract inflammation (empirical evidence of urinary tract inflammation in animals that had been catheterized manifested by bacteria in urine samples, pyuria, hematuria, pollakiuria, stranguria, or urethritis)	7.4 (4.5, 12.2)	9.0 (4.3, 18.5)	.53	1.8 (1.1, 2.9)	2.4 (1.2, 5.0)	.36
Acute respiratory disorders (evidence of upper or lower respiratory tract disorders evidenced by coughing, sneezing, nasal discharge, abnormal lung sounds, tachypnea, or dyspnea)	1.6 (1.1, 2.5)	2.1 (1.1, 3.8)	.48	0.5 (0.4, 0.8)	0.6 (0.3, 1.2)	.57
Gastrointestinal disorders (significant diarrhea, vomiting, or abdominal discomfort not predictably related to treatment)	4.0 (3.0, 5.3)	2.7 (1.6, 4.5)	.12	1.3 (1.0, 1.7)	0.8 (0.5, 1.4)	.08
Surgical site inflammation (apparent infectious problems related to surgical interventions manifested by redness, swelling, heat, or drainage at incision site, or inflammation or fluid accumulation at other sites)	10.1 (7.4, 13.7)	5.4 (2.7, 10.9)	.04	2.8 (2.1, 3.9)	1.5 (0.7, 3.0)	.04
Fever of unknown origin (temperature greater than 102.5°F that appears to be unrelated to other identifiable problems)	3.1 (2.3, 4.3)	2.7 (1.6, 4.4)	.46	1.0 (0.7, 1.4)	0.8 (0.5, 1.3)	.32
Septicemia (clinical or microbiological evidence of bacteremia or septicemia)	1.6 (1.0, 2.3)	0.5 (0.1, 2.0)	.07	0.5 (0.3, 0.7)	0.2 (0.04, 0.6)	.07

CI, confidence interval.
[a]Not related to the primary reason for hospitalization or an expected outcome of treatment.
[b]Proportion of animals with events among those affected adjusted for hospital of admission.
[c]Number of animals affected per 100 days of hospitalization adjusted for hospital of admission.
[d]*P*-value for difference between species.

surgery site inflammation, respectively. Once candidate models had been identified through backward selection, previously excluded variables were individually reintroduced to the model to ensure that the exclusion was appropriate. Confounding was identified by ≥20% change in parameter estimates when variables were individually removed from the multivariable models. When identified, confounding variables were forced into the multivariable models regardless of *P*-values. First order interaction terms for main effects variables included in final models were evaluated. Odds ratios (OR) and 95% CI were calculated using the results of logistic regression models.

Results

Dogs

Population Characteristics. Data were collected for a total of 1,535 dogs (Table 1). Mean age of dogs was 6.5 (95% CI, 6.3–6.7; SD, 4.2) years (median, 6 years; range, 6 months to 21 years). The population was evenly distributed between males and females and the majority of the population, regardless of sex, was neutered (81%). Animals were enrolled in approximately equal numbers from the 4 participating hospitals (Table 1). Approximately half of the dogs (56.6%) were admitted to either the medicine or surgery service of participating hospitals. The mean duration of hospitalization was 3.2 (95% CI, 3.0–3.4) days (median, 2 days; range, 1–48 days). Most of the dogs (71.2%) were hospitalized for ≤3 days and 12.7% (195) were hospitalized for ≥6 days. The most commonly performed procedure was placement of an intravenous catheter. Antimicrobial drugs given at times other than perioperatively were the most commonly used medication within

the study population. A large proportion of the population (41%) was admitted to the critical care unit on an emergency basis. The severity of illness in the study population is indicated by the overall mortality rate of 11.1%.

Occurrence of Nosocomial Syndromes – Crude Rates. Four hundred thirty-nine nosocomial events were reported to have occurred in 19.4% of (298/1,535) dogs. Individual hospitals had wide variability in the reported occurrence of ≥1 nosocomial event in dogs enrolled in the study, which ranged from 8.1% (26/321) to 36.0% (152/422). The individual nosocomial syndrome most commonly reported was surgical site inflammation, which occurred in 14.4% (93/647) of the dogs that underwent a surgical procedure. Surgical site inflammation was reported to have occurred in as few as 3.9% (4/102) and as many as 37.8% (51/135) of the dogs admitted from the individual institutions. Urinary tract inflammation was reported to have occurred in 11.4% (32/280) of the dogs that had a urinary catheter placed. Rates of occurrence of urinary tract inflammation associated with urinary catheterization at individual institutions varied from 4.6% (4/87) to 17.3% (19/110). Among dogs that had an intravenous catheter placed, 6.7% (101/1,508) were reported to have inflammation at the site of catheterization, with variability from individual institutions ranging from 4.1% (14/418) to 12.8% (53/415) of dogs. Appreciable gastrointestinal disorders were reported in 5.4% (83/1,535) of the dogs in this study, with a range from 1.2% (4/321) to 10.2% (43/422) of the dogs admitted at individual institutions. Fever of undetermined origin was reported in 4.8% (74/1,535) of dogs, varying from 0.9% (4/428) to 12.6% (53/422) of dogs from an individual institution. Acute respiratory disorders were reported in 2.2% (34/1,535) of dogs, variability from individual institutions ranged from 0.5% (2/428) to 5.2% (22/422). Septicemia was reported to have occurred in 1.6% (24/1,535) of dogs; the range of variability from individual institutions was 1.4% (5/364) to 1.9% (8/428).

Occurrence of Nosocomial Syndromes – Hospital Adjusted Rates. Overall, hospital adjusted rates of occurrence of nosocomial syndromes were slightly lower than the crude rates of occurrence (Table 2). Controlling for differences among hospitals, nosocomial syndromes were detected in 5.2 dogs (95% CI, 4.6–6.0) per 100 days of hospitalization. Although attack rates for specific events differed widely among hospitals, the incidence rates per 100 days of hospitalization were much less variable (Table 2).

Risk Factors for Nosocomial Syndromes. In general, the final multivariable models for each of the individually defined nosocomial syndromes were very similar to the final multivariable model investigating factors associated with the occurrence of any nosocomial syndrome. Therefore, only results for the multivariable model with the primary outcome being the occurrence of any nosocomial syndrome are presented here. Exposure variables meeting entry criteria for multivariable model selection of factors related to the outcome of any nosocomial syndrome were intravenous catheterization, urinary catheterization, surgical procedures, endotracheal intubation, gastrointestinal endoscopy, perioperative antimicrobial drugs, antimicrobial drugs given at times other than perioperatively, antiulcer medications, and duration of hospitalization. Variables retained in the model were intravenous catheterization, urinary catheterization, surgical procedure, antimicrobial drugs given at times other than perioperatively, antiulcer medications, and duration of hospitalization (Table 3). The exposure variable intravenous catheterization did not reach the critical α for retention, but was retained in the model because of the relation between the variable and the outcome of inflammation associated with intravenous catheterization. Interaction terms for main effects were not significant when included in the final model.

Table 3. Results for the final multivariable logistic regression model for risk factors associated with the occurrence of any nosocomial event in hospitalized dogs and cats.

		Dog			Cat		
Variable	Category	Odds Ratio	95% CI	*P*-Value	Odds Ratio	95% CI	*P*-Value
Any surgical procedure	Yes	2.18	1.62, 2.93	<.001	4.53	2.34, 8.74	<.001
	No	Reference			Reference		
Antiulcer medications	Yes	2.60	1.92, 3.52	<.001	3.89	2.06, 7.32	.001
	No	Reference			Reference		
Urinary catheter	Yes	1.60	1.15, 2.22	.005	2.96	1.49, 5.88	.002
	No	Reference			Reference		
Antimicrobials (not perioperative)	Yes	1.81	1.33, 2.46	<.001	Not significant		
	No	Reference					
Duration of hospitalization	6 or more days	3.02	2.08, 4.39	<.001	Not significant		
	4–5 days	1.23	0.85, 1.79				
	1–3 days	Reference					
IV catheter[a]	Yes	3.71	0.48, 28.86	.21	0.55	0.06, 4.74	.58
	No	Reference			Reference		

See methods section for details about modeling strategy.

[a]Retained in model because of the dependency with the outcome intravenous catheter site inflammation.

Cats

Population Characteristics. Data were collected for a total of 416 cats (Table 1). Mean age of cats was 7.9 (95% CI, 7.4–8.4; SD, 4.9) years (median, 7 years; range, 6 months to 23 years). The population was approximately evenly distributed between males and females and the majority were neutered (90.4%). Forty percent (167/416) of the subjects enrolled in the study were from one of the participating hospitals, the other hospitals contributed from 15.1% (63/416) to 26.9% (112/416) of the enrolled subjects. The mean duration of hospitalization was 3.3 (95% CI, 3.0–3.6) days (median, 2 days; range, 1–36 days). Most of the cats (69.5%) were hospitalized for ≤3 days, and 12.3% (51) were hospitalized for ≥6 days. The most commonly performed procedure was placement of an intravenous catheter. Antimicrobial drugs given at times other than perioperatively were the most commonly used medication within the study population. A large proportion of the population (52.9%) was admitted to the critical care unit on an emergency basis which is consistent with this population being considered high risk for exposure to potential risk factors for nosocomial events. The severity of illness in the study population is indicated by the overall mortality rate of 14.9%.

Occurrence of Nosocomial Syndromes – Crude Rates. Ninety-eight nosocomial events were reported to have occurred among 16.1% (67/416) of cats. Individual hospitals had wide variability in the reported occurrence of the different nosocomial syndromes among study subjects, which ranged from 4.1% (3/74) to 27.5% (46/167). The nosocomial event most commonly reported was urinary tract inflammation associated with placement of a urinary catheter. This syndrome was reported to have occurred in 15.5% (11/71) of the cats that had a urinary catheter placed, but all of these events were reported from only 2 institutions, with rates of 5.9% (1/17) and 31.7% (13/41), respectively. Surgical site inflammation was reported to have occurred in 10.1% (9/89) of the cats that underwent a surgical procedure, but all reports of inflammation at the surgical site came from 1 institution where 27.3% (9/33) of their surgical cats were affected. Of the cats that had an intravenous catheter placed, 5.7% (23/405) were reported to have inflammation at the site of catheterization, with variability from individual institutions ranging from 0.9% (1/110) to 11.7% (19/162) of cats. Significant gastrointestinal disorders were reported in 4.1% (17/416) of the cats in this study, and individual reports from institutions ranged from having no cases reported to 8.4% (14/167) of the cats affected. Fever of undetermined origin was reported in 5.3% (22/416) of cats, varying from 1.4% (1/74) to 9.0% (15/167) of cats from an individual institution. Acute respiratory disorders were reported in 3.4% (14/416) of cats, and reports from institutions varied from 1.4% (1/74) to 4.8% (8/167). Septicemia was reported to have occurred in 0.5% (2/416) of cats and all cases were reported from only 2 institutions.

Occurrence of Nosocomial Syndromes – Hospital Adjusted Rates. Overall, hospital adjusted rates of occurrence of nosocomial syndromes were slightly lower than the crude rates of occurrence (Table 2). Controlling for differences among hospitals, nosocomial syndromes were reported in 3.7 cats (95% CI, 2.9–4.8) per 100 days of hospitalization. Although attack rates for specific events differed widely (from 0.5 to 9.0%), the incidence rates per 100 days of hospitalization were much less variable (Table 2).

Risk Factors for Nosocomial Syndromes. In general, the final multivariable models for each of the individually defined nosocomial syndromes were very similar to the final multivariable model investigating factors associated with the occurrence of ≥1 nosocomial syndrome. Therefore, only results for analyses regarding the occurrence of ≥1 nosocomial syndrome are presented here. Exposure variables meeting entry criteria for multivariable model selection were sex/sex status, urinary catheterization, surgical procedures, device implanted at the time of surgery, endotracheal intubation, respiratory endoscopy, gastrointestinal endoscopy, antimicrobial drugs given perioperatively, antimicrobial drugs given at times other than perioperatively, antiulcer medications, and duration of hospitalization. Variables retained in the final multivariable model were intravenous catheterization, urinary catheterization, surgical procedure, and antiulcer medications (Table 3). The exposure variable intravenous catheterization did not reach the critical α for retention, but was retained in the model because of dependencies with the outcome of inflammation associated with intravenous catheterization. Interaction terms for main effects were not significant when included in the final model.

Discussion

This study was successful in obtaining estimates for the occurrence of HCAI among animals hospitalized in critical care using standardized surveillance for syndromic events at multiple referral centers. Previous studies reported regarding surveillance for specific types of HCAI in small animal hospitals have found similar frequency distributions in the individual types of HCAI that were detected, but all of these studies involved much smaller study populations than did the present study and were typically conducted at a single veterinary hospital.[21–27] As such, these reports have limited comparability to the present study. In addition, the animal population utilized for this study was considered to be at a higher risk of developing nosocomial syndromes during hospitalization because of the fact they were hospitalized in critical care units. Patients hospitalized in these settings have intrinsic risk factors associated with the underlying disease conditions that predispose them to adverse effects of extrinsic risk factors created by the procedures used for their care. Previous studies have shown the likelihood of acquiring HCAI in patients hospitalized in intensive care units is 5–10 times that of less critically ill patients in a hospital.[28] Therefore, we believe the rates estimated in this study are most relevant to this subset of hospitalized

animals, and are probably higher than would be seen in other less critically ill animals.

In the study reported here, we found positive associations regarding risk of nosocomial syndromes with increased duration of hospitalization, undergoing surgery, and placement of a urinary catheter. These findings are consistent with studies published for both hospitalized animals and humans.[4,25,26,29,30] Positive associations were also identified for animals that received antiulcer medications and those that received antimicrobial drugs at times other than perioperatively. Because data collected for this study were carried out only at the time of discharge, it is not possible to determine if the medications were given before or after the nosocomial syndrome occurred. Thus, it seems to be possible that some of these occurrences might have been responses to HCAI as opposed to causative exposures. However, previous studies have shown that the use of antimicrobials and antiulcer medications is associated with occurrence of HCAI, presumably because of perturbation of the microbiome in the gut and other locations.[31–36] Interestingly, in this study the rate that animals were reported to have ≥1 nosocomial syndrome was higher for dogs in comparison with events reported in cats ($P < .01$). It is unknown whether this difference is because of the differences in infection control practices when handling different species, whether dogs are more susceptible to developing HCAI, or whether intensity of surveillance efforts differed.

There was consensus among investigators from the different participating institutions that the syndromic surveillance method employed in this study was successfully standardized for use across multiple hospitals without interfering in established organizational structures. The simple 1 page survey could be quickly completed and entered into a database. Even with limited resources, the utilization of the surveillance technique was not hindered by different management or staffing and it did not interfere with implementation of other infection control practices. The effective collection of data from multiple institutions suggests that syndromic surveillance is a valuable tool for characterizing the occurrence of HCAI in small animal critical care facilities and, as applied here, added very little additional cost to the operating budgets of the participating hospitals.

No diagnostic test is perfect, and similarly no surveillance system provides perfect information about disease rates. By their nature, syndromic surveillance can be considered a type of screening test, and thus would tend to have greater sensitivity than specificity. We believe the syndromic surveillance method used here would be a more sensitive detection technique than passive data collection systems and perhaps greater sensitivity than many active surveillance strategies, though these systems would tend to have greater specificity. However, it is not clear whether the overall test accuracy for this syndromic surveillance system would be different than an active or passive surveillance system which used more definitive diagnostic criteria. Regardless of inaccuracies that might be inherent in this type of syndromic surveillance, if syndrome definitions and collection methods are standardized, the system will allow benchmarking for comparisons among different hospitals, different units within a single hospital, or comparisons over time within a hospital. We believe the relative ease and cost efficiency of gathering data using this syndromic approach to surveillance clearly outweighs limitations that might be associated with limitations in diagnostic accuracy that relate to syndromic determination of disease status.

Because of the paucity of previous reports regarding rates of HCAI collected systematically in multiple centers, it is not possible to know if the rates determined in this study are higher or lower than should be expected. However, the variability in rates of nosocomial syndromes determined from individual institutions suggests that a portion of the events detected in this study may have been preventable. We did not attempt to measure or account for differences in infection control practices used at the different study centers, nor did we attempt to account for differences among animals in their susceptibility to acquiring infections during hospitalization. Both of these factors could have contributed to variability in HAI rates that were estimated at different study centers. Because there are no comprehensive estimates of current rates of HCAI in veterinary medical facilities, it is not possible to know what the preventable proportion of infections was. The only way for the preventable fraction to be estimated would be through collection of data pertinent to the occurrence of HCAI in multiple healthcare facilities on an ongoing basis. It is only through this type of ongoing, multicentered effort that best evidence for decisions regarding acceptability of rates for HCAI can be obtained. This is essential for individual healthcare centers to make objective decisions regarding which disease prevention efforts are needed in order to optimize animal care by decreasing the risk for HCAI. It should be noted that the data reflected the collection of 3 months of data. There are likely seasonal, geographical, and case load related factors that each individual veterinary hospital needs to take into account.

We believe that the work presented here could represent a 1st step toward implementation of ongoing surveillance systems that are standardized and applied widely across multiple veterinary hospitals. The input from ongoing surveillance, whether collected continuously or intermittently, provides data that can be used to guide infection control practices, evaluate compliance with established infection control guidelines, and provide a logical basis for decisions regarding infection control policies.

Footnotes

[a] Copies of the surveillance form are available from the corresponding author on request.

[b] SAS 9.2; SAS Institute Inc, Cary, NC

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