Epidemiologic study of risk factors for lower urinary tract diseases in cats

Chalermpol Lekcharoensuk, DVM, MPH; Carl A. Osborne, DVM, PhD, DACVIM;
Jody P. Lulich, DVM, PhD, DACVIM

Objective—To determine proportional morbidity rates (PMR) and risk factors for lower urinary tract diseases (LUTD) in cats.

Design—Case-control study.

Sample Population—Records of 22,908 cats with LUTD and 263,168 cats without LUTD.

Procedure—Data were retrieved from the Purdue Veterinary Medical Data Base. Descriptive statistics and univariate logistic regression analyses were performed to assess whether breed, age, sex, and neutering status were associated with different causes of LUTD.

Results—Mean PMR for LUTD irrespective of cause was 8/100 cats (range, 2 to 13/100 cats). Increased risk for urocystolithiasis (Russian Blue, Himalayan, and Persian cats), bacterial urinary tract infections (UTI; Abyssinian cats), congenital urinary tract defects (Manx and Persian cats), and urinary incontinence (Manx cats) was detected. Cats between 2 and < 7 years of age had increased risk for urethral plugs, neurogenic disorders, congenital defects, and iatrogenic injuries. Cats between 4 and < 10 years of age had increased risk for urocystolithiasis, urethral obstructions, and idiopathic LUTD. Cats ≥ 10 years of age had increased risk for UTI and neoplasia. Castrated males had increased risk for each cause of LUTD except UTI and incontinence. Spayed females had increased risk for urocystolithiasis, UTI, and neoplasia. Sexually intact females had decreased risk for each cause of LUTD except neurogenic disorders and iatrogenic injuries.

Conclusion and Clinical Relevance—Specific breed, age, sex, and neutering status may be associated with specific types of feline LUTD. Knowledge of patient risk factors for LUTD may facilitate development of surveillance strategies that enhance earlier detection. (*J Am Vet Med Assoc* 2001;218:1429–1435)

Twenty-five years ago, Willeberg and Priester[1] reported results of an epidemiologic study of **lower urinary tract diseases (LUTD)** in cats based on 72,552 cats evaluated at 13 colleges of veterinary medicine in the United States and Canada between 1964 and 1973 and collected by the Purdue **Veterinary Medical Database (VMDB)**. As was the standard of practice at that time, they defined LUTD of cats as **feline urological syndrome (FUS)** and divided their cases for study into 2 groups: a urethral obstruction group and a cystitis group. The urethral obstruction group contained all records of cats with 1 or more admissions because of dysuria or anuria associated with distention of the urinary bladder. The cystitis group contained all records of cats with frequent voiding of small quantities of urine, with or without red discoloration.[2] On the basis of this epidemiologic study, a prototype representative of cats at increased risk for FUS was developed (neutered male overweight Persian cats that were 2 to 6 years old) and cited by authors for the next 25 years.[3-8]

The diagnostic term FUS, which was popularly used in the era of Willeberg and Priester's study, encompassed all forms of naturally occurring LUTD with different sites of involvement, different combinations of clinical signs, and fundamentally different causes.[9] Unfortunately, use of FUS as a diagnostic umbrella term fostered fundamental error in selection of cats for subsequent epidemiologic studies designed to investigate risk and protective factors.

In 1984, we recommended that the terminology of FUS be substituted with refined diagnostic terms pertaining to sites (eg, urethral, bladder), causes (eg, anatomic abnormalities; urolithiasis; bacterial, fungal, or parasitic infections; neoplasia; metabolic disturbances), morphologic changes (eg, inflammation, neoplasia), and pathophysiologic mechanisms (eg, obstructive uropathy, reflex dyssynergia).[10] If the underlying cause could not be identified after appropriate evaluation of cats with LUTD, we suggested that the term idiopathic LUTD be used, with the clear understanding that not all cases of idiopathic LUTD have the same primary cause.

Using this concept, the purpose of the epidemiologic study reported here was to determine **proportional morbidity rates (PMR)** and identify potential risk factors for specific types of these disorders in cats evaluated at several colleges of veterinary medicine that submitted data to the VMDB. Where possible, comparisons were made with findings reported by Willeberg and Priester[1] 25 years ago to identify similarities and differences in risk and protective factors.

Materials and Methods

Selection of cases—Data were retrieved from medical records for all cats evaluated at **Veterinary Teaching Hospitals (VTH)** in the United States and Canada that submitted data to the VMDB between 1980 and 1997. All colleges of veterinary medicine did not continuously contribute data to the VMDB from 1980 to 1997.

From the VMDB list,[a] 204 codes of diseases or clinical signs affecting the urinary bladder, urethra, and prostate gland were used to identify cats with LUTD. Cats with and without LUTD were counted only once; data related to readmissions were excluded. Because of the retrospective nature

From the Minnesota Urolith Center, Department of Small Animal Clinical Sciences, College of Veterinary Medicine, University of Minnesota, St Paul, MN 55108.

Supported in part by a grant from Hill's Science and Technology Center, 1035 NE 43rd St, Topeka, KS 66617.

The authors thank Yun Shen for technical assistance.

of this study, it was not possible to determine the extent of diagnostic evaluation for each patient.

Descriptions of breed, age, sex, weight, and hospital discharge status of all cats were defined according to VMDB classification.[a] Weights of all cats > 1 year of age were divided into 2 groups: < 6.8 kg (15 lb) and ≥ 6.8 kg (overweight).

Classification of causes of LUTD—To enhance analysis of data, the 204 codes of LUTD were divided into 12 causes: 1) urolith (urocystolith; urethral plug and urethrolith; and urocystolith, urethral plug, and urethrolith), 2) urethral obstruction, 3) infection (bacterial, viral), 4) trauma, 5) neurogenic causes, 6) postsurgical iatrogenic injuries, 7) congenital defects, 8) neoplasia, 9) urinary incontinence, 10) chemical- and drug-induced inflammation, 11) idiopathic, and 12) miscellaneous (bladder rupture, urethral disorders, prostate gland disorders, and others). For some cats, more than 1 cause of LUTD was recorded. Unfortunately, the VMDB did not distinguish between uroliths of different mineral compositions or between matrix-crystalline urethral plugs and urethroliths, as recommended by others.[11] Therefore, a diagnosis of urocystoliths in our study encompassed all types of minerals. Likewise, urethroliths in our study included both matrix-crystalline urethral plugs and uroliths. Idiopathic LUTD was an exclusion diagnosis established when underlying calculogenic, infectious, traumatic, neurogenic, iatrogenic, congenital, neoplastic, and drug- and chemical-induced inflammatory causes were not identified in affected cats. Cats with a diagnosis of FUS were placed in the category of idiopathic LUTD.

Statistical analyses—A computer software program was used to perform analyses.[12] The PMR of LUTD per 100 cats were calculated by dividing the number of cats with LUTD (× 100) by the total number of cats evaluated at each VTH. In addition, we also calculated yearly PMR of LUTD of cats admitted to all VTH. Comparisons of PMR of LUTD between the University of Minnesota and other institutions were performed by use of the 2 independence proportional test method.[13] **Odds ratios (OR)** and 95% **confidence intervals (CI)** of institutions submitting diagnosis, year of diagnosis, month of diagnosis, breed, age group, sex, weight, and status at discharge were calculated by the Woolf method.[14] If any expected cell values in the contingency table contained < 5 observations, the Fisher exact test was used to calculate the *P* value.[14] For comparison of OR of LUTD between institutions, the references used for institution, year, and month were the University of Minnesota, 1997, and December, respectively; the references used for cat breed, age group, and sex were domestic shorthair, between 4 and < 7 years, and sexually intact males, respectively.

For all cats, percentages of each of the 12 causes of LUTD were determined. If < 5 cats were detected in specific breed, age, or sex categories, this finding was interpreted as clinically unimportant, and these cats were not reported in our study. The Woolf method was used to calculate OR and 95% CI for breed, age group, and sex for each cause of LUTD. If any expected cell values in the contingency table contained < 5 observations, the Fisher exact test was used to calculate the *P*-value. For calculation of OR for breed, age group, and sex for each cause of LUTD, other breeds, other age groups, and other sexes, respectively, were used as the reference groups.

Odds ratios were rounded to the nearest hundredth of a decimal. Significant OR between 1.1 and 1.9 or between 0.5 and 0.9 were classified as weak associations. Significant OR > 2 (ie, risk) or < 0.5 (ie, protective) were classified as clinically (biologically) important. For all comparisons, a value of $P < 0.05$ was considered significant.

In order to investigate epidemiologic associations of specific causes of LUTD and facilitate comparison of the results of Willeberg and Priester's study[1] (1963 to 1974), which was designed to evaluate all cases of LUTD irrespective of causes, with our results (1980 to 1997), we separated our results into 2 major categories. The first category summarized data for all cases of LUTD irrespective of causes. The second category summarized data for specific causes of LUTD.

Results

For the period 1980 to 1997, 680,240 feline records were retrieved. After censoring records of multiple admissions from a single patient, 22,908 records of cats with LUTD and 263,168 records of cats without LUTD remained. The PMR of LUTD irrespective of cause was 8/100 cats.

The PMR for LUTD varied by VTH and were substantial. For example, the PMR for LUTD was approximately 2/100 cats at Tuskegee University, 8/100 cats at the University of Wisconsin and the University of Tennessee, and 13/100 cats at the University of Minnesota and University of Pennsylvania. With the exception of University of Pennsylvania, the PMR of all VTH were lower ($P < 0.05$) than that observed at the University of Minnesota.

When diagnoses of LUTD were grouped by year, substantial differences were not observed. However, weak associations were observed when diagnoses were grouped by month; LUTD were most commonly diagnosed in March (OR, 1.10; 95% CI, 1.02 to 1.17) and least commonly diagnosed in August (OR, 0.76; 95% CI, 0.71 to 0.81).

Persian, Manx, and Himalayan cats had increased risk for LUTD; Siamese cats had decreased risk (**Table 1**). Cats between 4 and < 7 years of age had the highest risk. Castrated males and spayed females had increased risk; sexually intact females had reduced risk. Overweight (≥ 6.8 kg [15 lb]) cats had increased risk for LUTD, compared with cats that weighed < 6.8 kg.

Mean duration of hospitalization for cats with LUTD was 2.0 ± 4.5 days, compared with 1.5 ± 4.9 days ($P < 0.05$) for cats with all other diseases. Of cats with LUTD, 95% (21,666/22,908) were discharged from the hospitals alive, whereas 92% (241,042/263,168) of cats with all other diseases were discharged alive ($P < 0.05$).

We compared results of our study (1980 to 1997) with those of an epidemiologic study of data from cats with LUTD compiled by the Purdue VMDB from 1963 to 1974 and reported by Willeberg and Priester in 1976[1] (**Table 2**). Although the 2 studies were similar inasmuch that data from both were derived from cats admitted to VTH in North America and complied by the VMDB, there are some notable differences in the methods used in the 2 studies. One difference was that a distinction between LUTD caused by bacterial infections, trauma, neoplasia, congenital disorders, and iatrogenic disorders was not included in Willeberg and Priester's study. A second difference was that those authors counted cats with and without LUTD more than once if they were seen at intervals > 1 year. A third difference was that Willeberg and Priester used the **relative risk (RR)** to evaluate risk for LUTD, whereas we used OR. To evaluate body weight as a risk factor, we

used only cats that were > 1 year of age, whereas they used cats of all ages. However, because the meaning of RR and OR are similar when used to evaluate a disease with low frequency,[14] it is possible to compare results of both studies.

When we used Willeberg and Priester's method of combining all causes of LUTD together in an effort to determine whether or not breed, age, sex, and body weight were potential risk factors, our results were similar to theirs. In both studies, weak associations for increased risk of LUTD were observed in Persian cats and in overweight cats. Likewise, weak associations for decreased risk of LUTD were found in Siamese cats in both studies. In both studies, a significant reduction in risk for LUTD was observed in sexually intact females. Whereas we observed a weak

Table 1—Odds ratios (OR) and 95% confidence intervals (CI) for breed, age group, sex, and weight in control cats and cats with lower urinary tract diseases (LUTD)

Variable	No. of cats with LUTD	No. of control cats	OR	95% CI
Breed				
DSH	11,948	134,207	1	NA
Persian	700	7,311	1.08	0.99–1.16
Siamese	1,273	15,888	0.90	0.85–0.96
Himalayan	464	4,002	1.30	1.18–1.44
Manx	174	1,471	1.33	1.13–1.56
Other	8,349	100,289	0.94	0.91–0.96
Age group (y)				
0–< 1	1,784	101,597	0.09	0.09–0.10
1–< 2	3,252	33,393	0.51	0.49–0.54
2–< 4	6,112	34,289	0.94	0.90–0.98
4–< 7	5,148	27,106	1	NA
7–< 10	2,499	18,575	0.71	0.67–0.75
10–< 15	2,307	25,652	0.47	0.45–0.50
≥ 15	924	8,656	0.56	0.52–0.61
Unknown	882	13,900	0.33	0.31–0.36
Sex				
Sexually intact female	1,514	63,380	0.39	0.36–0.41
Spayed female	5,715	66,595	1.38	1.33–1.45
Sexually intact male	3,716	59,952	1	NA
Castrated male	11,804	67,187	2.83	2.73–2.95
Unknown	159	6,054	0.42	0.36–0.50
Weight				
< 6.8 kg	15,131	106,148	1	NA
≥ 6.8 kg (15 lb)	1,205	6,182	1.37	1.28–1.46

DSH = Domestic shorthair. NA = Not applicable.

Table 2—Comparisons between a study of 72,552 cats from 1964 to 1973 and a study of 286,076 cats from 1980 to 1997

Risk factor and category for LUTD*	1964–1973 study		1980–1997 study	
	RR	*P* value	OR	99% CI
Breed[a]				
Persian	1.4	< 0.01	1.10	0.97–1.20
Manx	None detected		1.3	1.1–1.6
Himalayan	None detected		1.3	1.1–1.6
Siamese	0.8	< 0.01	0.94	0.90–0.98
Sex[b]				
Castrated male	1.6	< 0.01	2.8	2.7–3.0
Spayed female	0.6	< 0.01	1.4	1.3–1.5
Sexually intact female	0.3	< 0.01	0.39	0.36–0.42
Weight[c]				
Overweight	1.4	< 0.01	1.4	1.3–1.5
Month[d]				
March (highest)	1.3	< 0.01	1.096	1.003–1.198
July (lowest)	0.7	< 0.01	0.77	0.70–0.84

*LUTD was defined differently in the 2 studies (see Materials and Methods).
RR = Relative risk.
[a]Reference group was domestic shorthair breed.
[b]Reference group was sexually intact females.
[c]Reference group was weight < 6.8 kg (15 lb).
[d]Reference group was December.

Table 3—Diagnoses of LUTD in cats (No. [%]) in reports of 3 studies (1980–1997; 1982–1985; 1993–1995)

Diagnoses*	1980–1997 study	1982–1985 study[21]	1993–1995 study[22]
Urolith	2,209 (10)	62 (44)	16 (15)
Urocystolith	935 (4)	32 (23)	16 (15)
Urethral plug or urethrolith	1,224 (5)	30 (21)	NA
Urocystolith, urethral plug, or urethrolith	50 (0.2)	0 (0)	NA
Urethral obstruction	4,405 (19)	51 (36)	NA
Infection	2,789 (12)	4 (3)	1 (1)
Undefined	1,993 (9)	0 (0)	0 (0)
Bacterial	784 (3)	2 (2)	1 (1)
Viral	13 (0.1)	0 (0)	0 (0)
Trauma	409 (2)	0 (0)	0 (0)
Neurogenic causes	53 (0.2)	0 (0)	0 (0)
Postsurgical iatrogenic injuries	126 (0.6)	0 (0)	0 (0)
Congenital defects	152 (0.7)	0 (0)	12 (11)
Neoplasia	78 (0.3)	0 (0)	2 (2)
Urinary incontinence	892 (4)	0 (0)	0 (0)
Chemical and drug-induced inflammation	2 (< 0.1)	0 (0)	0 (0)
Idiopathic	14,467 (63)	77 (55)	80 (73)
Miscellaneous	544 (2)	0 (0)	0 (0)
Total	**22,908 (100)**	**141 (100)**	**109 (100)**

NA = Not applicable.
*More than 1 cause of LUTD was identified in some cats.

association for increased risk between LUTD and Manx and Himalayan breeds, these associations were not reported by Willeberg and Priester. We also observed a weak association for increased risk between spayed females and LUTD; Willeberg and Priester reported a significant reduction in the occurrence of LUTD in spayed females. In both studies, weak associations for increased risk of LUTD appeared to occur during the spring season. However, the magnitude of differences between the spring season and other seasons is unlikely to be biologically important.

Causes of LUTD

Urolithiasis or urethral plugs—Urolithiasis or urethral plugs were diagnosed in 10% (2,209/22,908) of cats with LUTD (**Table 3**). Forty-two percent (935) of the uroliths were retrieved from the urinary bladder, 55% (1,224) were from the urethra, and 2% (50) were from both the bladder and urethra.

Breeds with increased risk for urocystoliths were Russian Blue, Himalayan, and Persian (**Table 4**). Specific breeds with reduced risk were not detected. Cats between 4 and < 10 years of age had increased risk. Cats between 0 and < 2 years of age had decreased risk (**Table 5**). Spayed females and castrated males had increased risk; sexually intact females and sexually intact males had reduced risk.

Specific breeds with increased or reduced risk for urethroliths or urethral plugs were not detected. Cats between 2 and < 7 years of age had increased risk (Table 4). Cats between 0 and < 1 year of age and ≥ 15 years of age had decreased risk (Table 5). Castrated males had increased risk; sexually intact females and spayed females had reduced risk.

Specific breeds with increased or reduced risk for urocystholiths and urethroliths or urethral plugs were not detected. Cats between 4 and < 7 years of age and between 10 and < 15 years of age had increased risk (Table 4). Specific age groups with reduced risk were not observed (Table 5). Castrated males had increased risk. Specific sexes with reduced risk were not observed.

Urethral obstruction was diagnosed in 18% (4,045/22,908) of cats with LUTD. Specific breeds with increased risk were not observed. Burmese cats had reduced risk (Table 5). Cats between 2 and < 7 years of age had increased risk (Table 4). Cats between 0 and < 1 year of age and ≥ 15 years of age had decreased risk. Castrated males had increased risk; sexually intact females and spayed females had reduced risk.

Infections—Infections were diagnosed in 12% (2,789/22,908) of cats with urinary tract infections. Twenty-eight percent (n = 784) were caused by bacteria and 0.4% (13) were caused by viruses. In 72% (1,993) of LUTD, the cause was not specified.

Urethral obstruction—Identified pathogens for bacterial urinary tract infections included *Escherichia coli* (n = 363; 46%), *Staphylococcus* spp (73; 9%), *Streptococcus* spp (42; 5%), *Klebsiella* spp (26; 3%), *Proteus* spp (25; 3%), *Pseudomonas* spp (25; 3%), and *Pasteurella* spp (4; < 1%). In 31% (244) of cases, the type of bacteria was not specified. Abyssinian cats had increased risk for bacterial urinary tract infections (Table 4). Specific breeds with reduced risk were not detected. Cats > 10 years of age had increased risk. Cats between 0 and < 1 year of age had decreased risk

Table 4—Risk associations (OR > 2) between breed, age group, or sex and different causes of LUTD diagnosed from 1980 to 1997 in cats

	Sex				Breed				Age			
Causes	Type	No. of cats	OR	95% CI	Type	No. of cats	OR	95% CI	Range (Y)	No. of cats	OR	95% CI
Uroliths												
Urocystoliths	FS	393	2.1	1.9–2.4	Russian Blue	5	2.8*	NA	4 to < 7	275	3.6	3.2–4.2
	MC	396	2.1	1.9–2.4	Himalayan	38	2.7	2.0–3.8	7 to < 10	173	3.2	2.7–3.8
					Persian	54	2.1	1.6–2.8				
Urethroliths or									2 to < 4	395	0.2	2.8–3.6
urethral plugs	MC	863	7.0	6.2–7.9	ND	NA	NA	NA	4 to < 7	307	2.9	2.6–3.3
Urocystoliths,												
urethroliths, or									4 to < 7	19	5.3	3.0–9.4
urethral plugs	MC	38	9.2	4.8–17.7	ND	NA	NA	NA	10 to < 15	11	2.6*	NA
Urethral obstruction	MC	2,804	6.6	6.2–7.1	ND	NA	NA	NA	4 to < 7	1,343	3.3	3.1–3.6
									7 to < 10	994	2.8	2.6–3.1
Bacterial urinary tract									10 to < 15	179	2.7	2.3–3.2
infections	FS	355	2.4	2.1–2.8	Abyssinian	12	3.4*	NA	≥ 15	124	5.5	4.6–6.7
Neurogenic causes	MC	37	6.7	3.8–12.1	ND	NA	NA	NA	2 to < 4	17	3.2	1.8–5.6
									4 to < 7	14	3.1	1.7–5.8
Iatrogenic injuries	MC	107	16.3	10.1–26.8	ND	NA	NA	NA	2 to < 4	39	3.0	2.1–4.4
									4 to < 7	53	6.3	4.4–9.0
Congenital defects	MC	62	2.0	1.5–2.8	Persian	11	2.7*	NA	2 to < 4	35	2.0	1.4–2.9
									4 to < 7	39	3.0	2.1–4.3
Neoplasia	FS	32	2.1	1.3–3.2	ND	NA	NA	NA	10 to < 15	31	6.1	3.9–9.6
	MC	36	2.5	1.6–3.9					≥ 15	31	19.4	12.3–30.5
Incontinence	ND	NA	NA	NA	Manx	33	6.8	4.8–9.7	ND	NA	NA	NA
Idiopathic	MC	7,386	3.0	2.9–3.1	ND	NA	NA	NA	4 to < 7	4,098	2.6	2.5–2.7
									7 to < 10	3,353	2.6	2.5–2.7

*$P < 0.05$ from Fisher exact test was used if expected value was < 5.
ND = None detected. F = Sexually intact female. FS = Spayed female. M = Sexually intact male. MC = Castrated male.

Table 5—Protective associations (OR < 0.5) between breed, age group, and sex and different causes of LUTD diagnosed from 1980 to 1997 in cats

	Sex				Breed				Age			
Causes	Type	No. of cats	OR	95% CI	Type	No. of cats	OR	95% CI	Range (Y)	No. of cats	OR	95% CI
Uroliths												
Urocystoliths	F	64	0.23	0.18–0.30	ND	NA	NA	NA	0 to < 1	30	0.05	0.04–0.08
	M	79	0.31	0.25–0.39					1 to < 2	61	0.48	0.37–0.62
Urethroliths or	F	31	0.08	0.06–0.12					0 to < 1	69	0.10	0.07–0.12
urethral plugs	FS	124	0.33	0.28–0.40	ND	NA	NA	NA	≥ 15	5	0.12	0.05–0.29
Urethral obstruction	F	47	0.04	0.03–0.05	Burmese	8	0.49	0.24–0.98	0 to < 1	257	0.11	0.10–0.12
	FS	127	0.10	0.08–0.11					≥ 15	41	0.30	0.22–0.41
Bacterial urinary tract	F	59	0.26	0.20–0.33								
infections	M	86	0.42	0.33–0.52	ND	NA	NA	NA	0 to < 1	45	0.10	0.07–0.13
Trauma	F	51	0.45	0.33–0.60	ND	NA	NA	NA	ND	NA	NA	NA
	FS	52	0.43	0.32–0.58								
Neurogenic	ND	NA	NA	NA	ND	NA	NA	NA	0 to < 1	6	0.20	0.09–0.47
Iatrogenic injuries	M	14	0.42	0.24–0.74	ND	NA	NA	NA	1 to < 2	8	0.47	0.23–0.95
Congenital defects	F	13	0.29	0.17–0.52	Mixed-breed	32	0.48	0.32–0.71	0 to < 1	23	0.28	0.18–0.47
Neoplasia	F	5	0.22	0.09–0.53	ND	NA	NA	NA	ND	NA	NA	NA
Incontinence	F	117	0.48	0.39–0.58	ND	NA	NA	NA	0 to < 1	144	0.31	0.26–0.37
Idiopathic	F	982	0.23	0.22–0.25	ND	NA	NA	NA	0 to < 1	1,036	0.12	0.12–0.13

See Table 4 for Key.

(Table 5). Spayed females had increased risk; sexually intact females and sexually intact males had reduced risk. Specific breeds, ages, and sexes were not evaluated for viral infections because of the small number of cases (n = 13).

Trauma—Trauma was diagnosed in 2% (409/22,908) of cats with LUTD. Specific breeds and ages with increased or reduced risk were not observed. Specific sexes with increased risk were not detected. Sexually intact females and spayed females had reduced risk (Table 5).

Neurogenic causes—Neurogenic causes were diagnosed in 0.2% (53/22,908) of cats with LUTD. Specific breeds with increased or reduced risk were not observed. Cats between 2 and < 7 years of age had increased risk (Table 4). Cats between 0 and < 1 year of age had decreased risk (Table 5). Castrated males had increased risk. Specific sexes with reduced risk were not observed.

Iatrogenic injuries—Iatrogenic injuries were diagnosed in 0.6% (126/22,908) of cats with LUTD. Specific breeds with increased or reduced risk were not observed. Cats between 2 and < 7 years of age had increased risk (Table 4). Cats between 1 and < 2 years of age had decreased risk (Table 5). Castrated males had increased risk; spayed females and sexually intact males had reduced risk.

Congenital causes—Congenital defects were diagnosed in 0.7% (152/22,908) of cats with LUTD. Persians had increased risk (Table 4), whereas mixed-breed cats had reduced risk (Table 5). Cats between 2 and < 7 years of age had increased risk. Cats between 0 and < 1 year of age had decreased risk. Castrated males had increased risk; sexually intact females had reduced risk.

Neoplasia—Neoplasia was diagnosed in 0.3% (78/22,908) of cats with LUTD. Specific breeds with increased or reduced risk were not observed. Cats > 10 years of age had increased risk (Table 4). Specific age groups with reduced risk were not observed (Table 5). Spayed females and castrated males had increased risk; sexually intact females had reduced risk.

Drug- and chemically induced inflammation—Drug- and chemically induced inflammation was diagnosed in 0.01% (2/22,908) of cats with LUTD. Specific breeds, ages, and sexes with increased or reduced risk were not considered because of the small number of cases.

Urinary incontinence—Urinary incontinence was diagnosed in 4% (892/22,908) of cats with LUTD. Manx cats had increased risk (Table 4). Specific breeds with reduced risk were not observed. Specific age groups with increased risk were not observed. Cats between 0 and < 1 year of age had reduced risk (Table 5). Specific sexes with increased risk were not observed. Sexually intact females had reduced risk.

Idiopathic LUTD—Idiopathic LUTD were diagnosed in 63% (14,467/22,908) of cats with LUTD. A specific breed with increased or reduced risk was not observed. Cats between 2 and < 7 years of age had increased risk (Table 4). Cats between 0 and < 1 year of age had decreased risk (Table 5). Castrated males had increased risk; sexually intact females had reduced risk.

Miscellaneous causes—Miscellaneous causes (including bladder rupture and prostatic disorders) were diagnosed in 2% (544/22,908) of cats with LUTD. Specific breeds, ages, and sexes were not evaluated because of the small number of specific causes within this category.

Discussion

In the study reported here, the PMR of LUTD irrespective of causes represented the percentage of cats with LUTD in the entire population of cats admitted to participating VTH in North America. It may not reflect

PMR in private practices and does not reflect the true incidence rate of LUTD in the general population.[15] The wide variance in PMR reported by these VTH emphasizes the need for caution in formulating generalities about PMR of LUTD on the basis of reports from 1 center. On the basis of these results and our personal experience, we hypothesize that LUTD were more commonly recognized in VTH with special interests in these diseases. We further hypothesize that specific causes of LUTD may be underdiagnosed in hospitals without a special interest in urology. Because differences in PMR between institutions could also be related to other factors (environment, cat population characteristics, frequency with which owners seek veterinary care, etc), the validity of these hypotheses awaits results of appropriate studies designed to minimize confounding variables.

Comparison of results of our study to those reported by Willeberg and Priester confirmed that confounding errors are likely to occur when epidemiologic studies are designed to investigate risk and protective factors for LUTD without regard to underlying causes. Combining different causes into 1 nonspecific diagnosis appeared to conceal associations between some risk factors and specific diseases. Separation of LUTD into underlying causes unmasked significant risk or protective factors.

Significant associations between breed and some specific types of LUTD were apparent. Russian Blue cats had a 2.8 times greater risk of developing urocystoliths, compared with other cats. However, because mineral types of urocystoliths were not specified, further epidemiologic studies designed to evaluate associations between breeds and specific types of uroliths are indicated.

Himalayan cats had 2.7 times greater risk of developing urocystoliths, compared with other cats. Our findings are in agreement with results of a study[16] of 3,498 feline uroliths submitted to the Minnesota Urolith Center, in which Himalayan cats were found to have 4 times greater risk for calcium oxalate uroliths, compared with other cats.

We observed that Persian cats had 2.1 times greater risk for developing urocystoliths, compared with other cats. Similarly, in the study[16] of 3,498 feline uroliths submitted to the Minnesota Urolith Center, Persian cats had approximately 2.5 times greater risk for calcium oxalate uroliths, compared with other cats. In a study[17] of 84 feline uroliths submitted to the Urinary Stone Analysis Laboratory, University of California-Davis, Persian cats had approximately 8 times greater risk for calcium oxalate uroliths, compared with 258 age- and sex-matched control cats.

We observed that Persian cats had 2.5 times greater risk for developing LUTD diagnosed as congenital in origin, compared with other cats. Also, Abyssinian cats had approximately 3 times greater risk for developing bacterial urinary tract infections than other cats. However, further studies are needed to confirm these associations because of the small number of affected Persian and Abyssinian cats.

Manx cats had approximately 7 times greater risk of developing urinary incontinence than other cats. Although the identity of the underlying causes of incontinence in Manx cats was not specified by the VMDB, congenital syringomyelia, hydromyelia, myelomeningocele, and dysraphism of the spinal cord associated with urinary incontinence have been well-documented in this breed.[18-20]

Cats of mixed breeding were 0.5 times less likely to have congenital defects, compared with purebred cats. This association may be related, at least in part, to inbreeding of purebred cats. We hypothesize that outbreeding would reduce the predisposition of susceptible cats to inherited congenital disorders.

Burmese cats were 0.5 times less likely to have urethral obstruction than other cats. However, further studies are needed to confirm this association because of the small of number of affected Burmese cats evaluated.

Significant associations between age and some specific types of LUTD were apparent. Cats between 2 and < 7 years of age appeared to have increased risk for stones, plugs, or both in the urethra, neurogenic disorders, congenital defects, and iatrogenic injuries. Cats between 4 and < 10 years of age had increased risk for urocystolithiasis, urethral obstructions, and idiopathic LUTD. Cats > 10 years of age had increased risk for bacterial infections and neoplasia.

Castrated males appeared to have increased risk for all specific types of LUTD defined in this study. An association between spayed females and urocystolithiasis, bacterial infection, and neoplasia was apparent. Likewise, an association between sexually intact females and all specific types of LUTD, with the exception of neurogenic disorders and iatrogenic injuries, was observed. Our study was not designed to determine the underlying explanations for these associations.

The frequency of diagnosis of different causes of feline LUTD was prospectively evaluated at the University of Minnesota in the mid 1980s[21] and at The Ohio State University in the early 1990s[22] (Table 3). Because the inclusion and exclusion criteria of these 2 studies were substantially different from the criteria used in our study, many of the results of these studies do not lend themselves to direct comparison. For example, in the Minnesota study, the inclusion criteria specified 50 obstructed male cats. In contrast, the Ohio State study excluded obstructed male cats. Whereas 44% of the 141 cats in the Minnesota study had uroliths or urethral plugs, only 15% of the 109 cats in the Ohio State study had uroliths. Our study included male and female cats with and without urinary obstructions; only 10% of 22,908 cats had uroliths, urethral plugs, or both.

All 3 studies could be compared with reference to idiopathic LUTD, because, by definition, the cause could not be detected. This comparison revealed that idiopathic LUTD were identified in 63% of cats reported to the Purdue VMDB, 73% of cats in the Ohio State study, and 55% of cats in the Minnesota study.

It is often difficult to identify risk and protective factors associated with various naturally occurring diseases by classic experimental studies performed under controlled conditions, because these diseases are affected by many different factors, some of which are known and some of which are unknown. Therefore, these rela-

tionships are often evaluated by use of epidemiologic studies, of which the case-control study is a commonly used design. One of the advantages of case-control studies is that a number of potential risk and protective factors may be evaluated at one time. However, appropriate caution must be used in the interpretation of results. Although results of case-control studies are more reliable than uncontrolled clinical impressions, case-control studies do not prove a cause and effect relationship. A fundamental problem is that it is virtually impossible to identify a population of animals identical in every aspect except for the specific type of LUTD being investigated. Limitations are also associated with retrospective studies because of incomplete availability of desired information. Confirmation of the biological importance of hypothesized cause and effect relationships detected by case-control studies requires additional prospective or interventional studies.

In this retrospective case-control study, inconsistent use of uniform diagnostic terminology by participating VTH hindered our ability to classify specific causes of LUTD. This difficulty is emphasized by our need to classify 204 diagnostic codes into 12 basic causes. We recommend that those who contribute information to the Purdue VMDB strive to develop a uniformly accepted diagnostic classification. Likewise, we recommend that a consensus of agreement about diagnostic criteria used to define specific causes of LUTD be developed.

[a]Purdue Veterinary Medical Database, Purdue University, West Lafayette, Ind.

References

1. Willeberg P, Priester WA. Feline urological syndrome: association with some time, space, and individual patient factors. *Am J Vet Res* 1976;37:975–978.
2. Willeberg P. A case-control study of some fundamental determinants in the epidemiology of the feline urological syndrome. *Nord Vet Med* 1975,27:1–14.
3. Walker AD, Weaver AD, Anderson RS, et al. An epidemiological survey of the feline urological syndrome. *J Small Anim Pract* 1977;18:283–301.
4. Reif JS, Bovee KC, Gaskell CJ, et al. Feline urethral obstruction: a case-control study. *J Am Vet Med Assoc* 1977;170:1320–1324.
5. Bovee KC, Reif JS, Maguire TG, et al. Recurrence of feline urethral obstruction. *J Am Vet Med Assoc* 1979;174:93–96.
6. Lawler DF, Sjolin DW, Collins JE. Incidence rate of feline lower urinary tract disease in the United States. *Feline Pract* 1985; 15:13–16.
7. Barsanti JA, Finco DR, Brown SA. Diseases of the lower urinary tract. In: Sherding RG, ed. *The cat: diseases and clinical management*. 2nd ed. New York: Churchill Livingstone Inc, 1994; 1823–1969.
8. Willeberg P. Epidemiology of naturally occurring feline urologic syndrome. *Vet Clin North Am Small Anim Pract* 1984;14: 455–469.
9. Osborne CA, Kruger JM, Lulich JP, et al. Feline urological syndrome, feline lower urinary tract disease, feline interstitial cystitis: what's in a name? *J Am Vet Med Assoc* 1999;214:1470–1480.
10. Osborne, CA, Johnson GR, Polzin DJ, et al. Redefinition of the feline urologic syndrome: feline lower urinary tract disease with heterogenous causes. *Vet Clin North Am Small Anim Pract* 1984;14:409–438.
11. Osborne CA, Kruger JM, Lulich JP. Feline lower urinary tract disorders: definition of term and concepts. *Vet Clin North Am Small Anim Pract* 1996;26:169–179.
12. *SAS/STAT user's guide*. Version 6 edition. 4th ed. Cary, NC: SAS Institute Inc, 1994.
13. Snedecor GW, Cochran WG. *Statistical method*. 8th ed. Ames, Iowa: Iowa State University Press, 1989;124–125.
14. Schlesselman JJ. *Case-control studies*. New York: Oxford University Press, 1982;176–177, 180.
15. Kelsey JL, Whittemore AS, Evans AS, et al. *Methods in observational epidemiology*. 2nd ed. New York: Oxford University Press, 1996;34–37.
16. Thumchai R, Lulich JP, Osborne CA, et al. Epizootiologic evaluation of urolithiasis in cats: 3,498 cases (1982–1992). *J Am Vet Med Assoc* 1996;208:547–551.
17. Kirk CA, Ling GV, Franti CE, et al. Evaluation of factors associated with development of calcium oxalate urolithiasis in cats. *J Am Vet Med Assoc* 1995;207:1429–1434.
18. Kitchen H, Murray RE, Cockrell BY. Animal model for human disease: spina bifida, sacral dysgenesis and myelocele. *Am J Pathol* 1972;68:203–206.
19. Leipold HW, Huston S, Blauch B, et al. Congenital defects of the caudal vertebral column and spinal cord in Manx cats. *J Am Vet Med Assoc* 1974;164:520–523.
20. Lulich JP, Osborne CA, Lawler DF. Urologic disorders of immature cats. *Vet Clin North Am Small Anim Pract* 1987;17:663–696.
21. Kruger JM, Osborne CA, Goyal SM, et al. Clinical evaluation of cats with lower urinary tract disease. *J Am Vet Med Assoc* 1991;199:211–216.
22. Buffington CAT, Chew DJ, Kendall MS, et al. Clinical evaluation of cats with nonobstructive urinary tract diseases. *J Am Vet Med Assoc* 1997;210:46–50.