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Retrospective analysis of diagnoses and outcomes of 45 cats with micturition disorders presenting as urinary incontinence

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Abstract

Background: In contrast to dogs, the causes and outcomes of urinary incontinence (UI) in cats are largely unknown.

Objectives: To determine the causes, identify comorbid conditions, and assess outcomes of cats with micturition disorders presenting as UI.

Animals: Forty-five cats with UI.

Methods: Retrospective study. Medical records of cats presented from January 2006 to December 2017 were searched using 45 keywords related to UI. History, presenting complaint, and physical examination findings were used to confirm a diagnosis. Cases were categorized based on functional and anatomic localizations.

Results: Forty-five cats met inclusion criteria. Spinal cord disease was the most common cause of UI (n = 18), followed by urethral (n = 17), bladder (n = 9), and ureteral (n = 1) disorders. Proportions of voiding and storage phase disorders were similar (53% and 47%, respectively). However, voiding-phase disorders were observed more frequently in males and younger-aged cats ($P < .03$). Urinary tract infection was detected in 11 of 28 (39%) cats. Outcomes were available in 38/45 cases; 16 cats (42%) regained continence, 3 (8%) improved with treatment, and 19 (50%) remained incontinent or were euthanized. Multiple variable logistic regressions indicated that spinal cord disease was significantly more likely to be associated with poor outcomes compared to bladder or urethral disorders ($P < .04$).

Conclusions and Clinical Importance: Urinary incontinence in cats was associated with a variety of congenital and acquired disorders that affected both phases of micturition with similar frequency. Incontinent cats with spinal cord disorders were common and warrant a more guarded prognosis than do cats with bladder or urethral disorders.

KEYWORDS
bladder, ectopic ureter, FIC, spinal cord disease, ureter, urethra, urethral sphincter mechanism incompetence, urinary tract infection

1 | INTRODUCTION

Urinary incontinence (UI) is encountered uncommonly in cats,[1,2] and clinical observations indicate that the frequency and causes of UI in

Abbreviations: FeLV, feline leukemia virus; FIC, feline idiopathic cystitis; IQR, interquartile range; IVDD, intervertebral disk disease; UI, urinary incontinence; USMI, urethral sphincter mechanism incontinence; UTI, urinary tract infection.

cats are considerably different from those of dogs. In dogs, UI is the second most common lower urinary tract disease accounting for 24% of affected dogs.[3] Of these, storage phase micturition disorders such as acquired urethral sphincter mechanism incontinence (USMI) or ureteral ectopia accounted for most cases.[1,3] In cats, however, the proportional morbidity of UI as a cause of lower urinary tract disease is considerably lower.[2,4] In a survey of 24 veterinary teaching hospitals, UI accounted for only 4% of lower urinary tract disease diagnosed in cats over a 17-year period.[2] In another survey of lower urinary tract disorders in 81 geriatric cats, UI was diagnosed in only 5% of affected cats.[4]

Urinary incontinence in cats has been associated with over 43 congenital or acquired disorders affecting the spinal cord,[5-23] urinary bladder,[20,24-38] urethra,[20,28,29,39-50] or reproductive tract.[51-53] However, descriptions of disorders associated with UI in cats often have been limited to anecdotal case reports or selected case series. In a review of 19 cats with congenital UI, 10 cats had ureteral ectopia and 9 had congenital USMI.[20] In another series of 11 cats with acquired UI not associated with pelvic trauma, all affected cats had an idiopathic storage phase disorders, with 9 of 9 cats testing positive for feline leukemia virus (FeLV).[54] Larger and more comprehensive comparative studies of proportional morbidity of causes, clinical features, and outcome assessments of cats with UI have not been reported. Design of rational diagnostic approaches, selection of effective treatment strategies, and formulation of more accurate prognoses for cats with UI would be facilitated by more comprehensive knowledge of relative frequency of causes, clinical features, and outcomes. The purpose of our study was to determine the proportional morbidity of causes, characterize the clinical features, and assess outcomes of cats presented to a veterinary medical referral center for evaluation of UI over an 11-year period.

2 | MATERIALS AND METHODS

2.1 | Cases

Medical records of cats presented to the Michigan State University Veterinary Medical Center from 2006 to 2017 were searched electronically using 45 keywords related to abnormalities of micturition (see Data S1, Supplemental Information). Urinary incontinence was defined as any involuntary leakage of urine.[55-59] Cats were included if they had a presumptive diagnosis of UI based on owner observations of involuntary urine leakage (eg, dribbling, leaking, or soiling of bedding or owner's clothing while resting; involuntary hemorrhagic urine discharge) or observed involuntary urine dribbling or leaking on physical examination. Cats without UI and only owner-reported sign of voluntary micturition patterns such as polyuria, pollakiuria, or inappropriate behavioral urination were excluded. Cats with insufficient information to establish a presumptive diagnosis of UI were excluded. Additional follow-up information, when available, was obtained from referring veterinarians or owners by phone or email.

2.2 | Data collection

Data were collected retrospectively and tabulated in an electronic spreadsheet (Microsoft Excel 2016 16.0.67.2048, Microsoft Corp., Redmond, Washington) Data collected included sex, neuter status, breed, weight, date of birth, age at presentation, duration of clinical signs, physical examination findings (including bladder size), results of clinicopathologic, microbiologic, and diagnostic imaging evaluations, treatment, comorbid conditions, and outcomes. Urinary tract infection (UTI) was defined as isolation of $>1 \times 10^3$ colony-forming units (cfu)/ml urine in samples collected by cystocentesis or urinary catheterization.

2.3 | Data analysis

Cats were classified into functional groups by phase of micturition (voiding-phase or storage-phase disorders) based on physical examination or diagnostic imaging findings indicating a large, distended bladder (voiding phase disorder) versus a small bladder (storage phase disorder).[56-59] Cats also were classified into anatomic groups (spinal cord, bladder, ureteral, or urethral disorders) based on lesion localization.[58] Underlying causes were identified with as much specificity as possible for each cat based on history, physical examination findings, and results of clinicopathologic testing and diagnostic imaging. Cats with UI that coincided with an inflammatory lower urinary tract condition and that was characterized as a storage phase disorder associated with a small bladder and other lower urinary tract signs (eg, pollakiuria, stranguria, periuria) were classified as "inflammation-associated detrusor dysfunction." Outcomes were considered "favorable" if incontinence resolved or improved with treatment. Outcomes were considered "unfavorable" if UI did not response to treatment, or if cats were euthanized for causes related to their incontinence or comorbid diseases (eg, trauma). For univariable analyses, categorical data were compared using Fisher's exact test or Chi-squared analysis. Continuous data were assessed for normality using the Shapiro-Wilk test. Normally distributed results were compared using a Student's *t* test. Data that were not normally distributed were compared using a Mann-Whitney *U* test or Kruskal-Wallis 1-way ANOVA. Univariable analyses were performed using a statistical software package (SigmaStat 4.0, Systat Software, Inc., Point Richmond California) with a 0.05 type I error for significance. To evaluate the association of major risk factors on outcome, a multiple variable logistic regression modeling approach was used. The analysis was conducted in 2 stages. First, major risk factors hypothesized to influence outcome (favorable or unfavorable) were analyzed using the stepwise-backward approach. Risk factors included: (1) age group at the time of onset (juvenile, 0-6 months; young adult, 7-78 months; mature adult, 79-174 months; and geriatric, >174 months),[60] (2) anatomic site (spinal cord, urethra, and bladder), (3) micturition phase (voiding or storage phase), (4) presence of other neurological signs (yes or no), (5) presence of UTI (yes or no), and (6) treatment (surgical and medical management, or medical management alone). Results of the first analysis evaluating major risk factors indicated that anatomic site was the only factor that

TABLE 1 Causes of urinary incontinence in 45 cats grouped by phase of micturition affected and anatomic localization. Number in parentheses indicates number of cats

Micturition phase	Anatomic localization	Specific disorder
Voiding phase disorders (24)	Spinal cord (15)	Trauma (8)
		Cauda equina syndrome (7)
		Fracture/luxation (1)
		Neoplasia, undetermined (2)
		IVDD (2)
		Fibrocartilaginous emboli (1)
		Spinal dysraphism (1)
		Sacral malformation (1)
	Bladder (2)	Detrusor dysfunction, undetermined (2)
	Urethra (7)	FIC/urethritis (1)
		Urethral stricture (6)
		Post-perineal urethrostomy (4)
		Post-urethral catheterization (1)
		Idiopathic stricture (1)
Storage phase disorders (21)	Spinal cord (3)	Spinal dysraphism (Manx cat) (1)
		L7 lumbar spine malformation (1)
		Trauma, cauda equina syndrome (1)
	Ureter (1)	Bilateral ectopic ureters (1)
	Bladder (7)	Neoplasia, transitional cell carcinoma (1)
		Inflammation-associated detrusor dysfunction (presumed urge incontinence) (6)
		FIC (3)
		UTI (2)
		Ureteral stent + SUB + UTI (1)
	Urethra (10)	Urethral mass + urethral stent (2)
		Prostatic adenocarcinoma (1)
		Epithelial hyperplasia (1)
		Urethritis, post-urethral catheterization (1)
		Congenital urethral hypoplasia (1)
		Congenital USMI (2)
		Acquired USMI (1)
		Post-perineal urethrostomy (1)
		Urethral dysfunction, undetermined (2)

Abbreviations: FIC, feline idiopathic cystitis; IVDD, intervertebral disk disease; USMI, urethral sphincter mechanism incompetence; UTI, urinary tract infection.

significantly influenced outcome. Accordingly, the second analysis was aimed at identifying which of the anatomic sites had the greatest influence on outcome. Multivariable statistical analyses were performed using a statistical software package (JMP Pro 13.0.0, SAS Institute Inc., Cary, North Carolina) with 0.05 type I error for significance.

3 | RESULTS

Forty-five of 22 646 (0.17%) cats reviewed during the study period met inclusion criteria and included 22 spayed females, 22 castrated males, and 1 intact male cat. The overall median age of affected cats was 54 months (interquartile range [IQR], 21-144). The age distribution of affected cats was bimodal with 28 (62%) cats ≤5 years of age and 11 (25%) cats ≥12 years of age. Forty-one (91%) cats were mixed breed; 4 purebred cats included American Shorthair (1), Manx (2), and Turkish Van (1) breeds.

Causes of UI included congenital, acquired, and iatrogenic lesions of the spinal cord, ureters, bladder, and urethra (Table 1). The proportion of cats with voiding phase disorders (24/45, 53%) was similar to that of cats with storage phase disorders (21/45, 47%). When classified by anatomic localization, the most common site of disease was spinal cord (18/45, 40%), followed by urethra (17/45, 38%), bladder (9/45, 20%), and ureter (1/45, 2%). The most common pathophysiologic etiologies of UI were spinal cord trauma (9/45, 20%), congenital anomalies (8/45, 18%), urethral stricture (6/45, 13%), and inflammation-associated detrusor dysfunction (6/45, 13%). Congenital causes of UI were identified in 8/45 (18%) cats and included spinal canal malformations (4), congenital USMI (2), urethral hypoplasia (1), and bilateral ureteral ectopia (1). Incontinence was associated with iatrogenic causes in 10/45 (22%) cats and involved complications associated with perineal urethrostomy (5), urethral catheterization (2), and placement of urethral or ureteral stents (3). Overall, bacterial UTI was identified in 11 of 28 (39%) cats in which urine culture results were available. Other comorbid conditions included urine scalding, loss of tail tone or sensation, caudal paresis or paralysis, fecal incontinence, muscle atrophy, multiple trauma, and constipation. One or more additional neurological signs (loss of tail tone or sensation, caudal paresis or paralysis, or fecal incontinence) were reported in 16 of 45 (36%) cats.

When compared by functional classification (voiding versus storage phase of micturition), univariate analyses indicated that voiding phase disorders were significantly more common in male cats, whereas storage phase disorders were more common in female cats (Table 2; $P < .03$). Cats with voiding phase disorders were significantly younger than those with storage phase disorders (Table 2; $P < .05$) and were observed most commonly in the young adult age group (Figure 1). Although median serum creatinine concentration was significantly higher in cats with storage phase compared to voiding phase disorders (Table 2; $P < .01$), both values were within the normal reference interval. The proportion of voiding phase disorder cats with additional neurologic signs (loss of tail tone or sensation, caudal paresis or paralysis, or fecal incontinence) was significantly higher than storage phase disorder cats ($P < .01$). No significant differences were found between functional groups for breed, body weight, duration of clinical signs, and other serum biochemistry, urinalysis, or urine culture results.

When classified by anatomic localization, univariate analyses indicated that urethral disease was significantly more common in male cats (Table 3; $P < .04$). Cats with bladder disorders were significantly older than those in other anatomic groups (Table 3; $P < .01$). The proportion of spinal cord disease cats with other concomitant neurologic signs (loss of tail tone or sensation, caudal paresis or paralysis, or fecal incontinence) was significantly higher than cats with urethral or bladder disorders (*P* < .001). The limited numbers of cats with comorbid conditions in other anatomic groups precluded statistical analyses. No significant differences were found between anatomic groups for breed, body weight, duration of clinical signs, and serum biochemistry, urinalysis, and urine culture results.

TABLE 2 Demographic features, clinicopathologic findings, and clinical outcomes for 45 cats with urinary incontinence classified by phase of micturition affected

Feature	Voiding phase disorders	Storage phase disorders	*P*
Number	24/45 (53%)	21/45 (47%)	NA
Breed	22 Mixed (92%)	19 Mixed (91%)	NS
	2 Purebred (8%)	2 Purebred (9%)	
Sex	16 M (67%)	7 M (33%)	<.03
	8 F (33%)	14 F (67%)	
Age, median (IQR), mo	32 (12-53)	99 (9-173)	<.04
Duration of signs, median (IQR), d	21 (1-135)	150 (2-720)	NS
Other neurologic signs	13 (54%)	3 (17%)	<.01
Creatinine, median (IQR), mg/dL	1.2 (1.0-1.4)	1.5 (1.3-2.2)	<.01
USG, median (IQR)	1.046 (1.031-1.054)	1.047 (1.023-1.056)	NS
Urine culture positive	5/14 (36%)	6/14 (43%)	NS
Favorable outcome	8/22 (36%)	11/16 (69%)	NS

Abbreviations: F, female; IQR, interquartile range; M, male; NA, not applicable; NS, not significant; USG, urine specific gravity.

Several therapeutic agents and treatment modalities were used for specific and symptomatic management of disorders causing UI and associated comorbid conditions (see Data S2, Supplemental Information). The most common pharmacologic agents used for treatment of the 24 cats with voiding phase disorders included antimicrobials (12), opioid analgesics (10), anxiolytic drugs (5), alpha-1 adrenergic blockers (6), and bethanechol (4). The most common pharmacologic agents used for the 21 cats with storage phase disorders included antimicrobials (17), opioid analgesics (5), and phenylpropanolamine (5). Treatment with multiple modalities was common with 24/45 (53%) of affected cats receiving ≥3 different treatments. Of 21 cats treated with antimicrobials in which urine cultures were available, only 10 had confirmed bacterial UTI. Surgical interventions were performed in 8 voiding phase and 2 storage phase disorder cats (Data S2). Two cats also had tail amputations performed to facilitate hygiene. Some modalities were used exclusively to treat voiding phase disorder cats with spinal cord disease, including physical treatment, cold laser treatment, and daily at-home bladder expression (Data S2).

Outcomes were available for 38 cases. Nineteen cats (50%) had favorable outcomes with 16 regaining complete continence and 3 improving with treatment. Conditions associated with complete recovery included spinal cord trauma (3), feline idiopathic cystitis (FIC) (3), bacterial cystitis (2), ureteral stent (1), undetermined bladder dysfunction (1), urethritis (3), urethral stricture (2), and congenital USMI (1). Conditions associated with favorable, but incomplete, responses to treatment included congenital USMI (1), acquired USMI (1), and post-urethrostomy urethral stricture (1). The remaining 19 cats (50%) had unfavorable outcomes

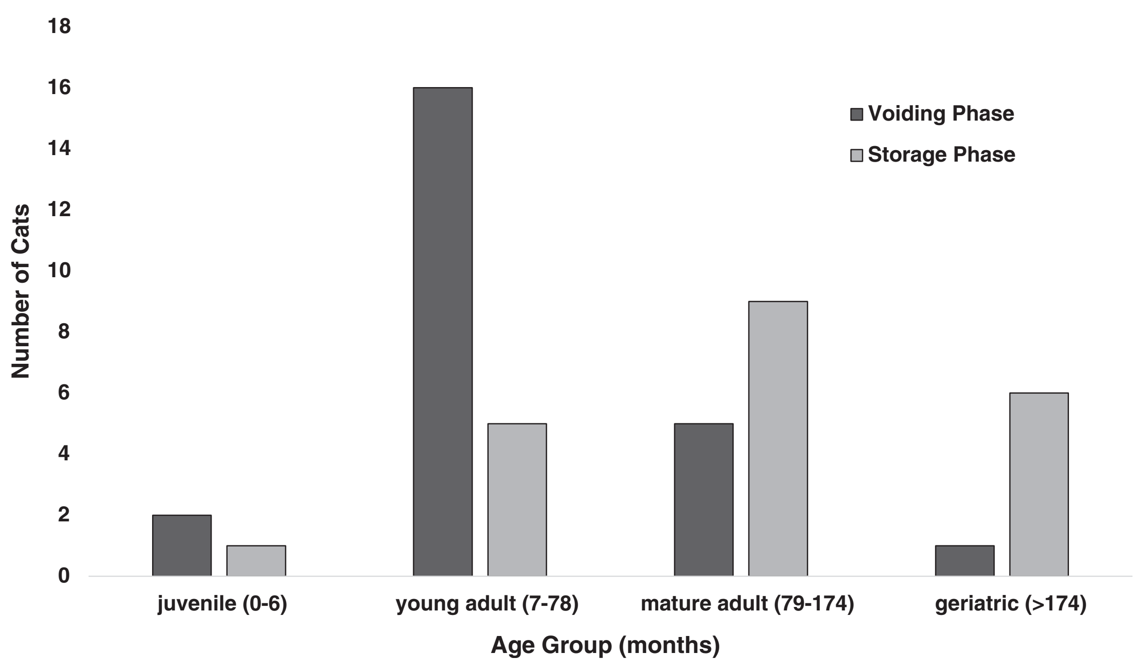

FIGURE 1 Frequency distribution of 45 cats with urinary incontinence by age group (juvenile 0-6 months, young adult 6-78 months, mature adult 79-174 months, and geriatric >174 months) and by phase of micturition affected (voiding phase, dark gray bar; storage phases, and light gray bar)

TABLE 3 Demographic features, clinicopathologic findings, and clinical outcomes for 45 cats with urinary incontinence categorized by anatomic lesion localization

Feature	Spinal cord	Bladder	Urethra	Ureter	*P*-value
Number	18/45 (40%)	9/45 (20%)	17/45 (38%)	1/45 (2%)	NA
Sex	8 M (44%)	2 M (22%)	17 M (67%)	0 M (0%)	<.04
	10 F (56%)	7 F (78%)	8 F (33%)	1 F (100%)	
Breed	16 Mixed (89%)	7 Mixed (78%)	17 Mixed (100%)	1 Mixed (100%)	NS
	2 Purebred (11%)	2 Purebred (22%)	0 Purebred (0%)	Purebred (0%)	
Age, median (IQR), mo	35 (7-86)	174 (90-199)	29 (8-82)	34 (NA)	<.01
Duration of signs, median (IQR), d	22 (1-198)	21.5 (1-112.5)	105 (10.3-180)	920 (NA)	NS
Other neurologic signs	15 (83%)	1 (11%)	3 (18%)	0 (0%)	<.001
SCr, median (IQR), mg/dL	1.3 (1.1-1.4)	1.5 (1.4-2.3)	1.2 (1.0-1.4)	2.2 (NA)	NS
USG, median (IQR)	1.047 (1.024-1.057)	1.029 (1.019-1.047)	1.047 (1.034-1.053)	1.056 (NA)	NS
Urine culture positive	2/9 (22%)	2/5 (40%)	6/13 (46%)	1/1 (100%)	NS
Favorable outcome	3/17 (18%)	7/8 (88%)	9/13 (69%)	NR	<.04

Abbreviations: F, female; IQR, interquartile range; M, male; NA, not applicable; NR, not reported; SCr, serum creatinine; USG, urine specific gravity.

TABLE 4 Influence of major risk factors on the outcome (favorable or unfavorable) in 45 cats with urinary incontinence

Risk factor	OR	CI	Prob > ChiSq
Anatomic site	0.030	0.002-0.350	.0324
Sex	2.357	0.640-8.676	.1928
Treatment	1.339	0.297-6.020	.2883
Age category[a]	…	…	.4915
Phase of micturition	0.259	0.066-1.020	.5208
Other neurological signs	0.109	0.023-0.513	.6829
UTI[a]	…	…	.7645

[a]Unable to calculate OR because of insufficient data.

TABLE 5 Influence of anatomical site on unfavorable outcome in 45 cats with urinary incontinence

Site of the lesion	Odds ratio (CI)	Increase risk
Urethra	…	…
Bladder	3.11 (0.281-34.41)	…
Spinal cord	0.095 (0.017-0.529)	2.67

(no improvement) including 11 cats that were euthanized. Conditions associated with unfavorable responses to treatment included spinal trauma (6), congenital spinal malformations (3), spinal neoplasia (2), intervertebral disk disease (2) fibrocartilaginous embolism (1), bladder neoplasia (1), urethral stricture (1), urethral hypoplasia (1), post-perineal urethrostomy (1), and prostatic neoplasia (1). Results of the stepwise backward multivariable regression analysis of major risk factors indicated that anatomic site was the only significant predictor of unfavorable outcome (*P* = .03; Table 4). The second logistic regression analysis was performed to determine the influence of anatomic site on outcome. No significant increase in the risk of an unfavorable outcome was observed if the lesion localized to the bladder or urethra (*P* = .32). However, spinal cord lesions were 2.67 times more likely to have an unfavorable outcome compared to urethral or bladder lesions (Table 5).

4 | DISCUSSION

Unlike dogs, studies describing the causes, treatments, and outcomes of cats with UI have largely been limited to case reports or case series focused primarily on congenital causes[20] or cases in which trauma was excluded.[54] To our knowledge, ours is the first comprehensive study characterizing the proportional morbidity of causes and outcomes of treatment associated with various causes of UI in cats. In our series of cats, UI was associated with a variety of congenital and acquired disorders that affected both phases of micturition with similar frequency. The proportional morbidity of causes, sex, age distribution, and outcomes of UI in our series of cats differed substantially from previous reports of UI in cats[5-55] and dogs.[1,61-65] Our observations indicated that spinal cord disorders were a common cause of UI in cats and were associated with less favorable outcomes compared to bladder and urethral disorders. Conversely, urethral and bladder disorders were associated with more favorable outcomes.

In our study, UI occurred with equal frequency between male and female cats. Voiding phase versus storage phase disorders also occurred with similar frequency. However, voiding phase disorders were significantly more common in male cats, whereas storage phase disorders were more common in female cats. This finding contrasts with that in dogs, in which UI is more commonly observed in females and usually is associated with storage phase disorders such as acquired USMI and congenital ureteral ectopia.[1,61-65] The reason for this disparity in the prevalence of causes of UI between dogs and cats is not completely understood, but may be related to species differences in urethral morphology and its effects on urethral mechanics for continence and micturition. Morphometric studies have shown that the feline urethra has more longitudinal smooth muscle and a narrower relative urethral lumen compared to dogs, resulting in twice the resistance to flow in the feline versus the canine urethra.[66,67] Furthermore, it has been hypothesized that the relatively longer internal urethral sphincter of the cat requires longitudinal smooth muscle contraction to actively shorten the urethra to facilitate sphincter opening.[66-68] Consequently, urethral disorders in cats may be less likely to be associated with UI.

4.1 | Spinal cord disease

When classified by anatomic site, spinal cord disease was identified in 18 of 45 (40%) incontinent cats and was the most common diagnosis associated with UI in our case series. In contrast, acquired or congenital urethral disorders were common causes of UI in dogs. In a study of 563 incontinent dogs,[1] only 9 (2%) were classified as having neurogenic incontinence. In our group of cats with spinal cord disease, incontinence was associated with trauma in 9 of 18 (50%) cats. Clinical findings in the majority of cats with trauma-induced spinal cord injury (8 of 9) were consistent with sacrococcygeal injury and cauda equina syndrome. Cauda equina syndrome is described in cats,[69-75] dogs,[76-79] and humans[81-83] as sensory or motor dysfunction or both resulting from injury to the terminal portion of the spinal cord and associated nerve roots. Clinical signs depend on the extent of injury to the spinal cord and peripheral nervous system and may include lumbosacral pain, tail analgesia and paralysis, fecal and UI, obstipation, pelvic limb paresis, and paresthesia.[69-83] The spectrum of clinical findings associated with sacrococcygeal injury and cauda equina syndrome is related to the fact that, in cats, the spinal cord generally extends to the last lumbar or first sacral vertebra[69,70,84] and the cauda equina extends to the first coccygeal vertebra.[70,78,84,85] Urinary incontinence and other micturition abnormalities have been reported with cauda equina syndrome in cats.[10,71,73-75]

Other spinal cord disorders observed in our series of incontinent cats included spinal cord neoplasia,[14,18] intervertebral disk disease (IVDD),[8,9] fibrocartilaginous embolism,[17] spinal dysraphism,[11,12] and vertebral malformations,[10] and have been reported previously. Importantly, results of our multivariable analyses indicated that spinal cord diseases were significantly more likely to be associated with an unfavorable outcome compared to urethral or bladder disorders. Furthermore, of the 11 cats that were euthanized, 8 had spinal cord lesions, and 3 of these cats were euthanized within 72 hours of initial presentation. Although the reasons for owners electing euthanasia are unknown, it is likely that the magnitude and extent of neurologic dysfunction, presence of other concomitant injuries or disorders, persistent incontinence despite treatment, and expense of treatment influenced owner decisions. Our observations suggest that UI associated with spinal cord disorders in cats warrants a guarded prognosis. In a previous retrospective study of 51 cats with traumatic sacrococcygeal injury, temporary or permanent UI was observed in 37 (73%) cats.[73] However, the prognosis for return of normal urinary function was good in cats with intact anal tone and perineal sensation on presentation. Return to normal urination occurred within 2 and 30 days, with a mean of 13 days; every cat that was unable to urinate normally by 30 days remained incontinent. Cats with tail flaccidity and urine retention on presentation had a very poor prognosis for recovery normal urinary function.

4.2 | Congenital disease

Congenital abnormalities accounted for only 18% of our series of incontinent cats and included 4 cats with congenital spinal canal malformations (eg, Manx syndrome or spinal dysraphism),[11,12] 1 cat with bilateral ureteral ectopia,[20-23] 2 cats with presumed congenital USMI,[20,30,39] and 1 cat with urethral hypoplasia.[20,53] These and other congenital causes of UI in cats have been reported previously.[19,23,27,33,46,86-88] It is difficult to draw conclusions on the proportional morbidity of congenital disorders in our series of cats because of relatively small numbers of affected cats and the fact that previous studies rarely reported congenital spinal cord diseases. In a previous study of 19 cats with congenital UI, 10 cats had ureteral ectopia and 9 had USMI and urethral hypoplasia.[20] However, that study included only cases of congenital ureteral ectopia and USMI or urethral hypoplasia, and did not include other causes of congenital UI, such as congenital spinal cord malformations[10-12] or other congenital urinary tract abnormalities.[86-88] When compared to dogs, the prevalence of congenital causes of UI in our series of cats was approximately one-half of that reported in canine populations.[1] In a study of 563 dogs with UI, 226 (38%) were diagnosed with congenital causes of UI including ureteral ectopia, congenital USMI, or intersex disorders.[1] Similar to surveys in cats, however, congenital causes of neurogenic incontinence in these dogs were not reported. The reason for this disparity between species is not fully understood but may be related to relative differences in the prevalence of ureteral ectopia in their respective populations. Although very rare in cats, ureteral ectopia is a common cause of UI in juvenile dogs.[1,87,88] In 1 study, ureteral ectopia accounted for >50% of cases of congenital UI in dogs.[1] Additional studies of larger populations of cats are needed to better characterize differences in the prevalence of congenital disorders causing UI in dogs and cats.

4.3 | Urethral disease

Urethral disorders were identified in 17 cats and represented the second most common anatomic category of causes of UI in our series. Diagnoses included urethral stricture, urethral stents, urethritis, congenital and acquired USMI, congenital urethral hypoplasia, post-perineal urethrostomy, and undetermined urethral dysfunction, all of which have been reported previously.[20,29,30,39,41,42,44,47,50] Other reported urethral disorders associated with UI in cats include urethral diverticulum,[46] prostatitis,[48] prostatic neoplasia,[40] reflex dyssynergia,[29,43,45] and epidural analgesia.[49] Urethral diseases were significantly more common in males, most likely because of increased frequency of iatrogenic injury occurring secondary to perineal urethrostomy (5 cats) or urethral catheterization (2 cats), which has been reported previously.[44,89] Outcomes were available for 13 cats and multivariable analyses indicated that urethral diseases had a higher likelihood of favorable outcome compared to spinal cord disease, with complete resolution or improvement observed in 69% of cats with urethral disease. A more favorable prognosis most likely reflected a higher prevalence of reversible or more readily treatable disorders (eg, urethral strictures, urethritis, congenital, or acquired USMI) in this disease category.

4.4 | Urinary bladder disease

Urinary bladder disorders were identified in 9 cats with UI and included both storage and voiding phase disorders. Diagnoses included inflammation-associated detrusor dysfunction (6 cats), neoplasia (1 cat), and detrusor dysfunction of undetermined cause (2 cats). All cats with inflammation-associated detrusor dysfunction had a concurrent inflammatory storage phase disorder associated with small bladders and other lower urinary tract signs including pollakiuria, stranguria, or periuria. Not surprisingly, UI resolved in these cats with elimination or remission of the concurrent inflammatory disorder. Although it is tempting to presume that these cats had urge incontinence, it is difficult to determine whether UI in these cats was caused by urge incontinence or some other cause of bladder instability or hyperreflexia. In people, urgency UI is the complaint of involuntary leakage accompanied by or immediately preceded by urgency.[90-92] Causes of urge incontinence in people include motor urgency (bladder overactivity), sensory urgency (eg, inflammation associated with UTI, urolithiasis, interstitial cystitis/painful bladder syndrome), neuropathic bladder dysfunction, urethral instability, and idiopathic disease.[90-92] In veterinary medicine, no clear consensus has been established for the definition of urge incontinence. In cats, urge incontinence has been defined as the inability to control micturition between the time of the urge to urinate and actual voiding and is characterized by urinary tract inflammation, loss of bladder compliance, and small bladder capacity.[55]

In our series, inflammation-associated storage phase incontinence was observed in 3 cats diagnosed with FIC, 2 cats with UTI, and in 1 cat after placement of a ureteral stent and SC ureteral bypass (SUB) device to treat bilateral ureteral obstruction. Urge incontinence has been reported by others in cats with UTI,[29] FIC,[29,59] urolithiasis,[28] bladder neoplasia,[35] and idiopathic detrusor instability.[32] However, to our knowledge, ours is the first report of incontinence associated with ureteral stent and SUB placement, although dysuria has been reported with these implants.[93,94] Idiopathic cystitis is a common lower urinary tract disorder of primarily young to middle-aged cats that is characterized by periuria, dysuria, pollakiuria, stranguria, and macroscopic hematuria.[95-97] In our series of cats with FIC, all had pollakiuria, hematuria, periuria, and dysuria in addition to UI. The specific behaviors described by owners related to UI included dribbling of urine, involuntarily voiding urine while at rest, and episodes of hemorrhagic urine discharge. In all cases, UI resolved completely with concomitant resolution of other lower urinary tract signs. Although FIC occurs commonly in cats, there are only anecdotal reports of UI secondary to FIC.[26,59] The lack of previous reports of UI secondary to FIC may simply be a consequence of the relatively low prevalence of UI as a sign of FIC.[95-98] Nevertheless, FIC should be considered as a differential diagnosis in all cats presenting with UI, especially those with concomitant lower urinary tract signs of cystitis in which UTI, neoplasia, and urolithiasis have been ruled out.

Overall, cats with bladder disease had the highest frequency of favorable outcome, with 88% cats having complete recovery of urinary continence. This finding is not unexpected because a majority of these cats had diseases that are easily treatable (eg, bacterial cystitis), or are in many cases self-limiting and likely to resolve in time with little or no treatment (eg, acute nonobstructive FIC).[96-100]

4.5 | Comorbid conditions-UTI

Urinary tract infection was detected commonly across all categories, occurring in 11 of 28 (39%) cats in which urine cultures were available. Bacterial UTI was detected with similar frequency among cats with voiding phase versus storage phase disorders. Bacterial UTI appeared to be a primary cause of UI in 3 cats with inflammation-associated incontinence, whereas UTI appeared to be a sequala of UI in the remaining cases. Although common, results of univariate and multivariable analyses indicated that UTI was not significantly associated with outcome. In a case-control study of 155 cats with UTI, UI was the strongest risk factor for developing UTI in cats.[101] Mechanisms that may favor development of UTI in incontinent cats include urine retention because of detrusor muscle areflexia or partial urethral obstruction for voiding phase disorders, or urine pooling or staining for storage phase disorders, resulting in a persistently wet perineum and an increased skin bacterial population, which may allow bacteria to ascend through the urethra and colonize the urinary bladder.[101-103]

4.6 | Treatments

A variety of therapeutic interventions were attempted; the majority (53%) of cats received >3 treatments. Because of the large number of therapeutic modalities employed, it is difficult to assess the impact of any single treatment on outcome. Whereas half of the cats undergoing surgery for a potentially reversible lesion had favorable outcomes, multivariable analyses indicated that surgery in combination with medical management was not associated with more favorable outcomes compared with medical management alone. However, this observation should be viewed cautiously. Based on limited sample size and inability to control for other concomitant treatments, we cannot exclude the possibility of type II statistical error. Similarly, insufficient numbers of cats treated with other specific medical modalities precluded statistical analysis.

It is noteworthy that none of the cats treated with the alpha-adrenergic drug phenylpropanolamine in which follow-up was available (5 of 6 cats) were reported to have responded favorably to the medication. Four of these cats were classified as having storage phase disorders (2 with congenital USMI, 1 with acquired USMI, and 1 with a transitional

L7 vertebra); 1 cat was classified as having a voiding phase disorder (cauda equina syndrome). Poor responses to phenylpropanolamine similarly were observed by others in 3 cats with congenital USMI[39] and in 2 cats with urethral insufficiency after perineal urethrostomy, that showed no improvement in clinical signs or urethral pressure profiles with phenylpropanolamine administration.[29] However, other reports have described more favorable responses to phenylpropanolamine including a cat with UI caused by feline leukemia-related myelopathy[54] and a kitten with genitourinary dysplasia that improved dramatically after reconstructive surgery and became fully continent when phenylpropanolamine was administered.[53] In contrast to cats, phenylpropanolamine has a high rate of clinical success in female dogs with acquired USMI, with continence rates of 85 to 90% after 28 days of treatment.[104-106] Similar controlled studies investigating the safety and efficacy of phenylpropanolamine for treatment of UI in cats have not been reported. The reason for this apparent species disparity in response to phenylpropanolamine is unknown. It is possible that morphometric differences in feline versus canine urethral smooth muscle results in decreased responsiveness to the effects of phenylpropanolamine in cats.[66,67] However, proof of this hypothesis requires further investigation.

4.7 | Limitations

Our study had several limitations, predominantly because of its retrospective nature and the diversity of causes and treatments encountered in our population of cats. Some reported causes of UI were not represented in our study, such as dysautonomia,[36] UI secondary to FeLV,[5] bladder torsion,[31] and various genitourinary congenital abnormalities.[51-53] Diagnostic testing was performed in each case at the discretion of the clinician, and no standardized diagnostic protocol was followed. Unless involuntary urine leakage was observed on physical examination (as it was in some, but not all cases), owner observations often were used as a primary means of diagnosing UI. Owners may not have been aware that UI is a passive process or may have mischaracterized other abnormal voiding behaviors such as pollakiuria or periuria as incontinence. Similarly, owner-reported behaviors of urgency (stranguria, pollakiuria, periuria) also were used to define inflammation-associated detrusor dysfunction in cats with storage phase UI. To minimize the risk of misdiagnosis, the owner's history was carefully reviewed in each case by the authors to identify other descriptors (eg, urine leakage, dribbling, bloody urine discharge, wet bedding, or soiling of owner's clothing while resting) that would be consistent with a diagnosis of UI.

Although outcomes were available for most cats, follow-up information was obtained from owners or primary care veterinarians at variable time periods after diagnosis and treatment. In addition, all cats did not undergo a standardized comprehensive evaluation. Although these limitations could result in misclassification error, all cats included in the study were deemed to have sufficient data to determine functional and anatomic classifications. Unfortunately, the number and diversity of disorders and the fact that management often involved multiple treatments, largely precluded assessment of the impact of individual treatments on outcome. Consequently, we chose to limit assessment of treatment to 2 broad categories of medical management with or without surgery. Doing so allowed assessment of potential confounding of surgical disorders or interventions on outcome. Although no significant effect was identified, the relatively small sample size for each disease in the treatment category increased the risk of type II statistical error. Additional studies are needed to evaluate the effect of disease processes as well as specific treatment on outcome. However, because of the low prevalence of UI in cats in our population (only 0.2% of cases over 11 years), larger multicenter studies likely would be required to achieve timely collection of adequate sample size.

5 | CONCLUSION

In summary, results of our study indicate that the proportional morbidity of the causes of UI in cats differs substantially from that of dogs. Spinal cord disorders were the most common cause of UI in our series of cats and were more likely to have an unfavorable outcome compared to bladder and urethral disorders. Conversely, urethral and bladder disorders, especially those causing urgency incontinence, were associated with more favorable outcomes. A large number of therapeutic agents and modalities were used for management of UI in our series of cats. However, because of the diversity of disorders and number of therapeutic agents involved, it was difficult to assess the efficacy of any single agent. The uncertainly surrounding optimal management of UI in cats is compounded by the lack of controlled studies investigating the efficacy and safety of treatments used for cats with UI. Future large-scale clinical studies will be necessary to further characterize the causes of UI cats and identify safe and effective management strategies.

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CONFLICT OF INTEREST DECLARATION

Authors declare no conflict of interest.

OFF-LABEL ANTIMICROBIAL DECLARATION

Authors declare no off-label use of antimicrobials.

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC) OR OTHER APPROVAL DECLARATION

Authors declare no IACUC or other approval was needed.

HUMAN ETHICS APPROVAL DECLARATION

Authors declare human ethics approval was not needed for this study.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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