ASSOCIATIONS BETWEEN ULTRASOUND AND CLINICAL FINDINGS IN 87 CATS WITH URETHRAL OBSTRUCTION

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Urethral obstruction is a life-threatening form of feline lower urinary tract disease. Ultrasonographic risk factors for reobstruction have not been previously reported. Purposes of this retrospective cross-sectional study were to describe urinary tract ultrasound findings in cats following acute urethral obstruction and determine whether ultrasound findings were associated with reobstruction. Inclusion criteria were a physical examination and history consistent with urethral obstruction, an abdominal ultrasound including a full evaluation of the urinary system within 24 h of hospitalization, and no cystocentesis prior to ultrasound examination. Medical records for included cats were reviewed and presence of azotemia, hyperkalemia, positive urine culture, and duration of hospitalization were recorded. For medically treated cats with available outcome data, presence of reobstruction was also recorded. Ultrasound images were reviewed and urinary tract characteristics were recorded. A total of 87 cats met inclusion criteria. Common ultrasound findings for the bladder included echogenic urine sediment, bladder wall thickening, pericystic effusion, hyperechoic pericystic fat, and increased urinary echoes; and for the kidneys/ureters included pyelectasia, renomegaly, perirenal effusion, hyperechoic perirenal fat, and ureteral dilation. Six-month postdischarge outcomes were available for 61 medically treated cats and 21 of these cats had reobstruction. No findings were associated with an increased risk of reobstruction. Ultrasonographic perirenal effusion was associated with severe hyperkalemia ($P = 0.009$, relative risk 5.75, 95% confidence interval [1.54–21.51]). Findings supported the use of ultrasound as an adjunct for treatment planning in cats presented with urethral obstruction but not as a method for predicting risk of reobstruction.

Key words: feline, reobstruction, ultrasound, urolithiasis, urethral obstruction.

Introduction

Urethral obstruction is a life-threatening form of feline lower urinary tract disease (FLUTD). Common etiologies may include urethral plugs, urolithiasis, urethral stricture, or idiopathic obstruction, and less commonly neoplasia, anatomical malformation, or foreign body. Of cats with lower urinary tract disease, urethral obstruction has been reported to occur in 18%–58%.[1–5] Identified clinical risk factors for urethral obstruction include young age, higher body weight, higher mean urine specific gravity, lower urine pH on presentation, pyuria, hematuria, struvite crystalluria, and increased urine protein:creatinine ratio.[6,7]

After an initial episode of urethral obstruction, reported rates of recurring obstruction range between 14.8% and 36%.[3,6,8] Various potential predisposing factors to recurring obstruction have been identified and include being indoor only cats compared to indoor–outdoor cats, as well as cats consuming dry food only,[6] although type of food consumed did not play a role in one study.[3] A recent retrospective study also showed a significant association between catheter size or use of antispasmodic drugs, and recurrent obstruction.[10] Most other factors evaluated were not significantly associated with an increased risk of reobstruction. Although the role of clinical and laboratory findings in the risks for recurring obstruction have been relatively well studied,[6,7,9,10] the imaging findings—in particular ultrasonographic findings—in cats with urethral obstruction, and their potential association with an increased risk for reobstruction have not been reported.

Objectives of this retrospective cross-sectional study were to describe the prevalence of urinary system ultrasonographic changes in cats with acute urethral obstruction within 24 h following emergency relief of obstruction; and to test associations among ultrasound findings, recurrence

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in cats treated medically, clinicopathologic findings (severity of azotemia, severe hyperkalemia, and a positive urine culture), and length of hospitalization. We hypothesized that some ultrasound findings may be associated with patient outcome (reobstruction vs. no reobstruction). For example, cats with cystoliths, more severe sediment, and more severe bladder thickening may have an increased risk of reobstruction. Cats with severe bladder thickening and visible sediment on ultrasound may require longer hospitalizations due to the need for prolonged medical management. Also, some ultrasound findings may be associated with clinicopathologic findings including that cats presenting with more severe bloodwork and electrolyte abnormalities (severe azotemia and severe hyperkalemia) may have more chronic obstructions and therefore more severe sonographic changes including bladder wall thickening, perirenal effusion, renomegaly, significant pyelectasia, or ureteral dilation.

Methods

Medical records from cats presenting to the Matthew J. Ryan Veterinary Hospital at the University of Pennsylvania between October 2011 and January 2013 were retrospectively evaluated. Inclusion criteria were a physical examination and history consistent with urethral obstruction, an abdominal ultrasound including a full evaluation of the urinary system within 24 h of hospitalization, and no cystocentesis prior to ultrasound examination. Urethral patency was achieved through catheterization in all cats prior to ultrasound. Medical record data recorded included: patient signalment (breed, sex, age, weight, body condition); history of previous episodes of obstructive FLUTD; clinical laboratory values at presentation; presence of struvite crystals on urinalysis; urine culture results; and hospitalization duration. Azotemia was graded as mild-to-moderate or severe,[11,12] with mild-to-moderate azotemia defined as a creatinine concentration within 2–5 mg/dl, and severe azotemia greater than 5 mg/dl. Severe hyperkalemia was defined as greater or equal to 8 mEq/l, similar to prior studies.[9,10] Urine culture results were only recorded if the urine sample was obtained from urine collected at initial catheterization via a newly placed catheter, which is the standard hospital practice. Quantitative urine cultures for the catheterized samples were performed, and cultures with less than 1000 colony-forming units per ml (cfu/ml) were considered likely to be a contaminant per prior reports and therefore recorded as negative for statistical purposes.[13–15] The standard recommendation for hospitalization at our institution is 2 days, so hospitalization lengths greater than 2 days were considered extended. Type of treatment received was recorded and included surgical (perineal urethrostomy, cystotomy) or medical, which typically included indwelling catheterization with urine output monitoring, intravenous fluids, and pain medication with discharge recommendations to increase water consumption, utilize an appropriate number of litter boxes, and decrease stress. Six-month postdischarge clinical outcomes were obtained through reviewing the medical record if considered complete, and phone interviews with the owners or primary care veterinarians. Cats that underwent perineal urethrostomies were excluded from followup. Cats that reobstructed on the same day following catheter removal were recorded as a minimum of 1 day to reobstruction. Only cats that reobstructed within the six-month period were categorized as having reobstructed for comparison with ultrasound results.

Static ultrasound images and cine loops were retrieved from the Picture Archiving and Communication System (Philips iSite Radiology 3.5.0., Royal Philips Electronics, Amsterdam, The Netherlands). Ultrasound images were evaluated by the first author with no knowledge of the detailed history other than the presentation for urethral obstruction, and no information about the outcome and laboratory findings. Recorded criteria included:

- For the urinary bladder: Presence of cystolithiasis (yes/no), urine echogenicity (severity of floating urinary foci graded 0–2 for anechoic to mildly echogenic [considered normal],[16] moderately echogenic, or severely echogenic, respectively), urine sediment at the dependent portion of the lumen (graded 0–4 for absent, mild, moderate, or severe, respectively), presence of suspended linear strands (yes/no), bladder wall thickening (yes/no, with the threshold defined as a wall thickness $\geq$2.3 mm, which is the reported upper limit across all levels of distention),[17,18] pericystic peritoneal effusion (yes/no), hyperechoic pericystic fat (yes/no). Additional abnormalities that were seen but not listed above were also recorded, when identified.
- For the kidneys/ureters: retroperitoneal effusion (yes/no), hyperechoic perirenal/periureteral fat (yes/no), maximum pyelectasia diameters (measured from the pelvic crest to ureter, with significant pyelectasia defined as >3.4 mm),[19] renomegaly (defined as a renal length greater than 4.3 cm),[20,21] abnormal renal cortical echogenicity (recorded as hyperechoic if iso or hyperechoic to the liver [if image was available] or if increased contrast between cortex and medulla, and recorded as hypoechoic if there was decreased contrast between cortex and medulla echogenicities),[22] chronic renal changes (irregular kidneys of small or normal size with irregular cortex/medulla and poorly demarcated corticomedullary junction), ureteral dilation (defined as persistence of fluid within the ureteral lumen), and maximum ureteral diameters.

Urethral changes were not recorded as all cats were catheterized at the time of the ultrasound examination. The bladder wall thickness measurement was not recorded when the bladder was empty or not appropriately distended with urine or saline at the time of examination. Original reports were evaluated following retrospective image evaluation for details on whether saline was injected into the bladder.

Statistical analyses were performed by a single author (W.M.) using a commercially available statistical software package (Intercooled Stata 10.0 for Windows, College Station, TX). Normality of descriptive data was determined by visual inspection of probability plots against a 95% confidence interval. Descriptive statistics of data with normal distribution were reported as mean ± standard deviation, and non-normally distributed data were reported as median and range. Five multinomial logistic regression analyses were performed to evaluate associations between ultrasound changes and the following dependent variables: reobstruction, severe azotemia, severe hyperkalemia, a positive urine culture, and an extended length of hospitalization. The independent ultrasound variables included in the logistic regression analysis evaluating reobstruction included: renomegaly (yes/no), perirenal effusion (yes/no), ureteral dilation (yes/no), significant pyelectasia (present if >3.4 mm), bladder wall thickening (yes/no, cutoff ≥2.3 mm), presence of cystic calculi (yes/no), urine echogenicity (graded 0–2), linear floating urinary echoes (yes/no), severity of urine sediment (graded 0–4), pericystic effusion (yes/no), and obstruction order (first vs. recurrent). Independent variables included in the regression analyses evaluating severe azotemia, severe hyperkalemia, positive urine culture, and an extended length of hospitalization included: renomegaly, perirenal effusion, chronic renal changes, ureteral dilation, significant pyelectasia, bladder wall thickening, presence of cystic calculi, urine echogenicity, linear floating echoes, severity of urine sediment, pericystic effusion, and obstruction order. *P*-values were computed for each predictor in each regression analysis, and corrected for multiple comparisons by multiplying the computed *P*-value by the number of times a given predictor appeared across all five logistic regression analysis. The corrected *P*-values were considered statistically significant at $P < 0.05$. Relative risk ratios and 95% confidence intervals were calculated for the ultrasound predictors that were significantly associated with the outcomes.

Results

Eighty-seven cats were included in this study. Represented breeds were domestic short hair (74/87, 85.0%), domestic long hair (9/87, 10.3%), and one each (1.1%) of Persian, Russian Blue, Maine Coon, and Chartreux. All cats were male; 83 were castrated, four intact. Median age was 4.6 years (range 0.7–13.0). Median weight was 5.7 kg (range 3.5–12.8) with body conditions recorded as obese (9/87, 10.3%), overweight (38/87, 43.7%), normal (33/87, 37.9%), underweight (2/87, 2.3%), and unknown (5/87, 5.7%). For 78 of 87 cats (89.7%), this was the first episode of urethral obstruction. Bloodwork pertaining to renal function was unavailable in five of 87 cats. Twenty-eight out of 82 cats (34.1%) were nonazotemic, 19/82 (23.2%) were mild to moderately azotemic, and 35/82 (42.7%) were severely azotemic. Of the 84 cats for which potassium measurements were available, 33 of 84 cats (39.3%) were severely hyperkalemic. Urinalysis results were available in 71 of 87 cats. Struvite crystals were observed in 20 of 71 cats (28.2%). Urine culture results were available in 64 of 87 cats. Of these, nine cats (14.1%) had a positive urine culture with greater than 1000 cfu/ml per bacteria species. Eight cats had a single bacterial species and one cat had both *Escherichia coli* and *Pasteurella multocida*. Bacterial isolates included *Escherichia coli* ($n = 3$), *Staphylococcus pseudointermedius* ($n = 2$), *Streptococcus sp.* ($n = 1$), *Pasteurella multocida* ($n = 3$), and *Enterobacter cloacae* ($n = 1$). For 6/9 cats with a positive urine culture this was the first obstruction episode, and for 3/9 cats this was a recurrent obstruction episode. Median hospitalization duration was 2 days (range 0–8 days). Sixty-four cats had hospitalizations less than or equal to 2 days, while 23 cats had hospital durations greater than 2 days, which was considered extended.

All ultrasound examinations had been performed using the same equipment (GE Medical LOGIQ9, Ultrasound Imaging System, General Electric Medical Systems, Milwaukee, WI) with a combination of microconvex (8 MHz) or linear (10–14 MHz) transducers. The majority of images were obtained using harmonics. Multiple operators, who were either board-certified veterinary radiologists or radiology residents under the supervision of a board-certified veterinary radiologist, performed the examinations. If the bladder was poorly distended, 10–15 ml of sterile saline was infused in most cases. One of 87 ultrasound examinations was considered within normal limits. Abnormal ultrasound findings for the urinary bladder and pericystic peritoneal space are summarized in Table 1. Ultrasound findings for the kidneys, ureters, and retroperitoneal space are summarized in Table 2. Both tables also summarize ultrasound findings for patient subgroups, including outcome (reobstruction or no reobstruction), azotemia severity, and hyperkalemia severity.

The most common abnormalities associated with the urinary bladder included the presence of sediment (Fig. 1D–F), increased urine echogenicity (Fig. 1A–C), bladder wall thickening, pericystic effusion, and increased echogenicity of the pericystic fat (Fig. 2). Additional ultrasound findings not listed in the evaluated criteria in Table 1 included four cats with large echogenic soft tissue septa extending across the urinary bladder lumen resembling pseudomembranous cystitis (Fig. 3),[23] and four cats with large

TABLE 1. Summary of Ultrasound Findings Associated with the Bladder in All Cats and Across Subdivisions

Bladder Findings	All cats	Reobstruction†		Severe azotemia‡		Severe hyperkalemia	
		Yes	No	Yes	No	Yes	No
Number of cats per group	$n = 87$ (100)*	21	40	35	47	33	51
Urine sediment (all)	73 (84.0)	17 (81.0)	32 (80.0)	28 (80.0)	41 (87.2)	27 (81.8)	44 (86.3)
Mild	24 (27.6)	4 (19.0)	9 (22.5)	8 (22.9)	15 (31.9)	8 (24.2)	16 (31.4)
Moderate	29 (33.3)	9 (42.9)	12 (30.0)	9 (25.7)	18 (38.3)	8 (24.2)	19 (37.3)
Severe	20 (23.0)	4 (19.0)	11 (27.5)	11 (31.4)	8 (17.0)	11 (33.3)	9 (17.6)
Urine echogenicity							
Anechoic-mild (normal)	43 (49.4)	14 (66.7)	14 (35.0)	20 (57.1)	20 (42.6)	17 (51.5)	24 (47.1)
Moderate	27 (31.0)	5 (23.8)	17 (42.5)	12 (34.3)	13 (27.7)	13 (39.4)	14 (27.5)
Severe	17 (19.5)	2 (9.5)	9 (22.5)	3 (8.6)	14 (29.8)	3 (9.1)	13 (25.5)
Suspended linear strands	17 (19.5)	3 (14.3)	8 (20.0)	11 (31.4)	5 (10.6)	10 (30.3)	7 (13.7)
Bladder thickening§	76 (89.4)	19 (90.5)	33 (86.8)**	34 (97.1)	37 (82.2)††	32 (97.0)	41 (83.7)‡‡
Cystolithiasis	41 (47.1)	11 (52.4)	15 (37.5)	18 (51.4)	21 (44.7)	19 (57.6)	22 (43.1)
Hyperechoic pericystic fat	52 (59.8)	10 (47.6)	26 (65.0)	18 (51.4)	29 (61.7)	18 (54.5)	31 (60.8)
Pericystic effusion	52 (59.8)	12 (57.1)	25 (62.5)	21 (60.0)	28 (59.6)	18 (54.5)	32 (62.7)

*Number of cats with that finding (n) and corresponding percentage (%) for that group in parentheses.
†Medically treated cats only
‡Creatinine values were available for 82 cats, and potassium values were available for 84 cats.
§Only 85 of the total cats had recorded bladder thicknesses, numbers adjusted accordingly.
**Out of 38 cats.
††Out of 45 cats.
‡‡Out of 49 cats.

TABLE 2. Summary of Ultrasound Findings Associated with the Kidneys and Ureters in All Cats and Across Various Subdivisions

Kidney/ureter findings	All cats	Reobstruction†		Severe azotemia‡		Severe hyperkalemia	
		Yes	No	Yes	No	Yes	No
Number of cats per group	$n = 87$ (100)*	21	40	35	47	33	51
Renomegaly	37 (42.5)	7 (33.3)	15 (37.5)	19 (54.3)	13 (27.7)	19 (57.6)	16 (31.4)
Unilateral	14 (16.1)	3 (14.3)	6 (15.0)	4 (11.4)	6 (12.8)	5 (15.2)	8 (15.7)
Bilateral	23 (26.4)	4 (19.0)	9 (22.5)	15 (42.9)	7 (14.9)	14 (42.4)	8 (15.7)
Pyelectasia	52 (60.0)	15 (71.4)	19 (47.5)	26 (74.3)	21 (44.7)	26 (78.8)	24 (47.1)
Pyelectasia >3.4 mm	9 (10.3%)	1 (4.8)	4 (10.0)	6 (17.1)	1 (2.1)	7 (21.2)	2 (3.9)
Ureteral dilation	21 (24.1)	8 (38.1)	6 (15.0)	16 (45.7)	4 (8.5)	14 (42.4)	7 (13.7)
Hyperechoic periureteral fat	13 (14.9)	3 (14.3)	5 (12.5)	5 (14.3)	7 (14.9)	5 (15.2)	8 (15.7)
Hyperechioc perinephric fat	32 (36.8)	8 (38.1)	14 (35.0)	20 (57.1)	10 (21.3)	20 (60.6)	11 (21.6)
Retroperitoneal effusion	31 (35.6)	10 (47.6)	11 (27.5)	19 (54.3)	9 (19.1)	19 (57.6)	10 (15.6)
Hyperechoic cortex	9 (10.3)	3 (14.3)	3 (7.5)	6 (17.1)	3 (6.4)	6 (18.2)	2 (0.03)
Hypoechoic cortex	1 (1.1)	0	0	1 (2.9)	0	1 (3.0)	0
Irregular renal margin	15 (17.2)	2 (9.5)	6 (15.0)	7 (20.0)	6 (12.8)	7 (21.2)	8 (12.5)
Decreased corticomedullary definition	18 (20.7)	8 (38.1)	4 (10.0)	11 (31.4)	6 (12.8)	10 (30.3)	8 (12.5)

*Number of cats with that finding (n) and corresponding percentage (%) for that group in parentheses.
†Medically treated cats only.
‡Creatinine values were available for 82 cats, and potassium values were available for 84 cats.

intraluminal echogenic structures (ranging from 30 to 47 mm diameter) presumed to be large blood clots, three of which contained hyperechoic material (Fig. 4). For the kidneys and ureters, the three most common findings included pyelectasia, renomegaly, and perirenal effusion. Bladder wall thickening was present in 76/85 cats (89.4%). Only two cats had relatively empty bladders that were not distended with saline, therefore bladder thickness was not recorded. Excluding these two cats, the median bladder wall thickness was 4.0 mm, range 1.4–27.5 mm. The largest thickness (27.5 mm) was presumed to be an intramural hematoma, and this patient reobstructed 26 days following discharge (Fig. 3D). Excluding this mass, the median thickness was still 4.0 mm, range 1.4–10.0 mm. Cystolithiasis was identified in 41/87 cats (47.1%); the median size of calculi was 2.0 mm (range 0.5–17.0 mm). Two cats had too much sediment to accurately measure the largest calculi. Unilateral ureteroliths were identified in three cats (ureteroliths were all 1–2 mm).

Pyelectasia was seen in 52/87 cats (60%) with a median pelvic dilation of 2.3 mm (range 0.5–12.0 mm). Nine of 87 cats (10.3%) had pyelectasia >3.4 mm. Pyelectasia was asymmetrical by more than 1.0 mm in 29 of these 52 cats with an overall median pyelectasia difference (maximum diameter minus minimum diameter) of 1.0 mm (range of 0.5–9.4 mm). The three cats with ureteroliths had pyelectasia asymmetry of 0.6, 1.0, and 2.0 mm. Maximum pyelectasia for those three cats was 1.2, 3.0, and 2.0 mm, respectively.

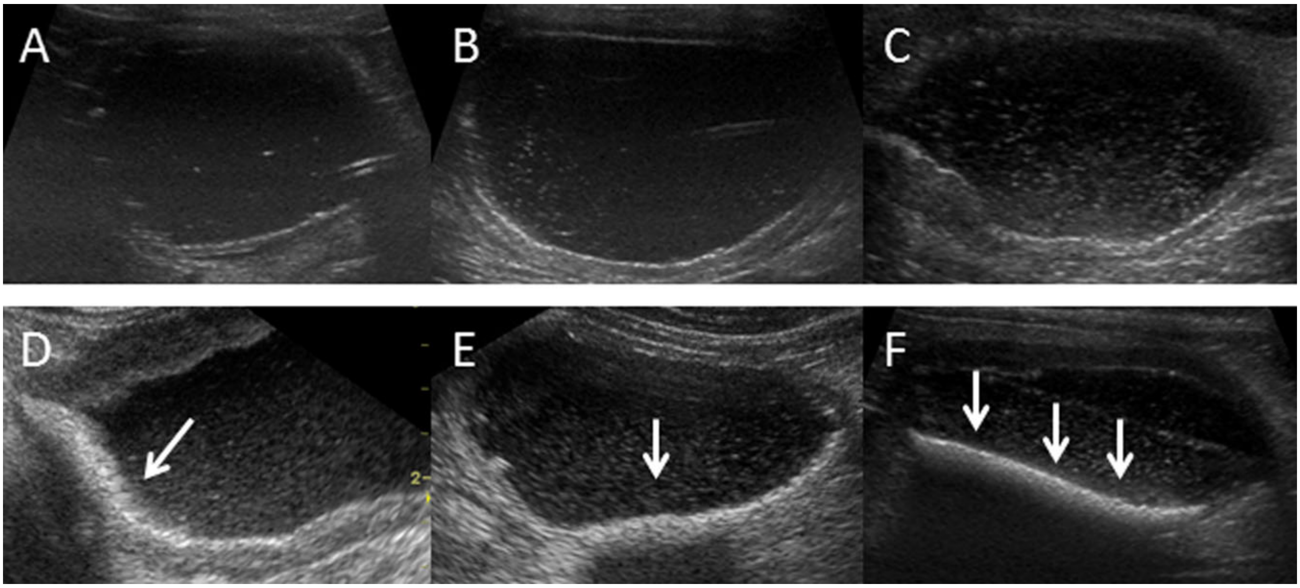

FIG. 1. Ultrasound images showing representative grades of urine echogenicity and urine sediment. Grades for urine echogenicity are shown in (A–C) representing mild, moderate, and severe urine echogenicity, respectively. Anechoic urine is not shown, which would have been graded as zero. Images (D–F) display mild, moderate, and severe dependent luminal sediment, respectively.

The ureteroliths were contralateral to the larger pelvis in two cats with 0.6 and 2.0 mm asymmetry, and ipsilateral in the cat with 1.0 mm pelvic dilation asymmetry. Ureteral dilation was found in 21/87 cats (24.1%); median maximum ureteral dilation was 2.0 mm (range 1.3–5.8 mm).

Eighty-two of 87 cats (94.3%) survived to discharge. One cat died in hospital and four cats were euthanized during the initial hospitalization; one due to owners perception of poor prognosis (mass in bladder lumen, chance of reobstruction, or need for surgery), one due to urethral rupture, and two were euthanized following owner declining recommended cystotomy. Within the initial episode, five cats received cystotomies and three cats received perineal urethrostomies. Seventy-four of the surviving cats were treated medically, and of these 13 were lost to followup. Forty of the 61 medically treated cats (65.6%) with follow-up information had not reobstructed as of 6 months after discharge, and 21/61 (34.4%) had reobstructed within the 6-month period (of which 13 [21.3%] reobstructed within 14 days). Only one of the 21 cats that reobstructed had two urethral obstruction episodes prior to presenting at our institution, and the remaining 20 had no prior episodes. Cats that had prior episodes of urethral obstruction were not at an increased risk of reobstruction (uncorrected P value of 0.948) within the 6-month follow-up period. The median time to reobstruction was 7 days (range 1–163 days) postdischarge. Excluding cats lost to followup, 11 of 26 (42.3%) medically treated cats with cystic calculi reobstructed in the 6-month follow-up period, and 10 out of 35 (28.6%) medically treated cats without cystoliths reobstructed. Of the three cats with presumptive large intraluminal blood clots, one of these cats was euthanized following the ultrasound, one cat reobstructed 6 days following discharge (9 days after initial presentation), and two cats did not reobstruct during the follow-up period. One of these cats that did not reobstruct had a follow-up ultrasound performed 15 days following the first ultrasound and the previously identified 33 mm intraluminal mass was no longer present (Fig. 3). Only one of the four cats with large echogenic septa resembling pseudomembranous cystitis reobstructed within the follow-up period, which also was the only cat to have a large intramural mass presumed to be an intramural hematoma (same cat described above with the 27.5 mm wall thickness).

Multinomial logistic regression showed that none of the ultrasound findings evaluated or first episode vs. recurrent obstruction presentations were associated with reobstruction. Cats with perirenal retroperitoneal effusion were more likely to have severe hyperkalemia (corrected P-value = 0.045, relative risk 5.75, 95% confidence interval [1.54–21.51]). None of the ultrasound findings evaluated were significantly associated with severe azotemia, a positive urine culture, or an extended length of hospitalization.

Discussion

To the authors' knowledge, this is the first report detailing ultrasonographic findings of the urinary tract following urethral obstruction in a large group of cats. In addition to the presence of sediment and bladder wall thickening, also commonly seen with nonobstructive lower urinary tract disease,[24] we found a high prevalence of additional findings in cases of urethral obstruction, including pericystic

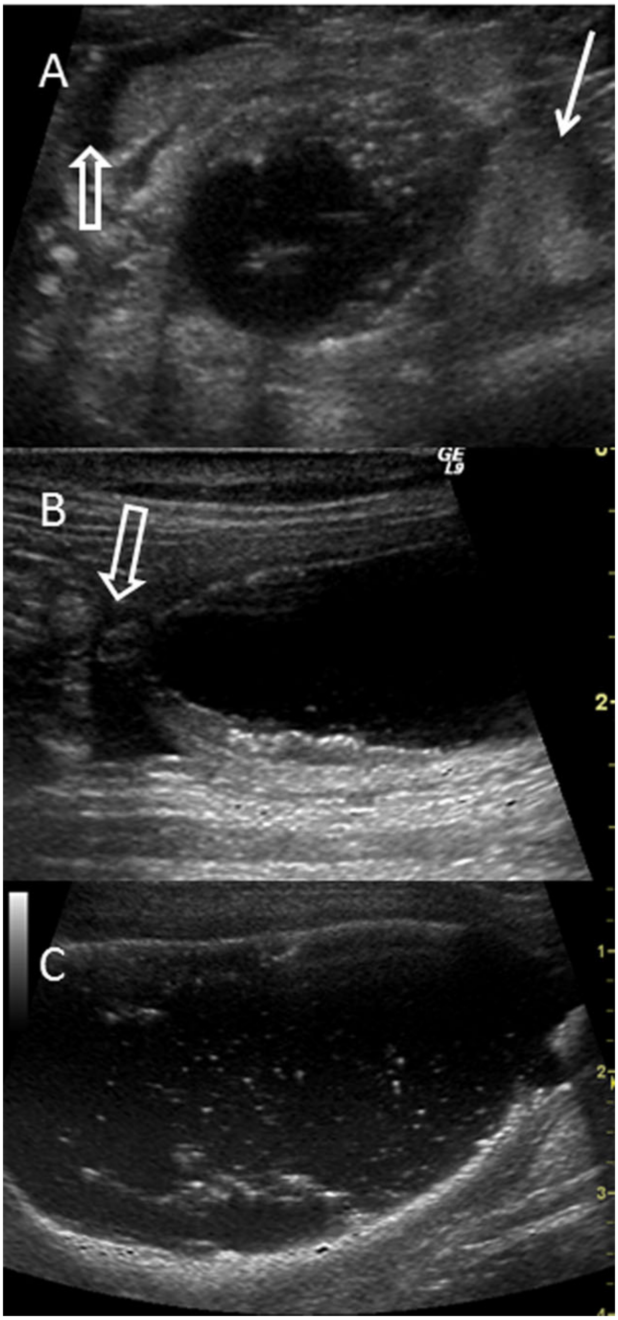

FIG. 2. Ultrasound images of various bladder findings following urethral obstruction. (A) Parasagittal image displaying hyperechoic pericystic fat (arrow), echogenic pericystic effusion (open arrow), and adhered echogenic urinary debris. (B) Bladder of a cat with pericystic effusion (open arrow), with concurrent bladder wall thickening and mild hyperechoic urinary sediment. (C) Thin, linear, echogenic strand of material adhered to the bladder mucosa, which may represent congealed sediment, inflammation, or hemorrhage.

effusion and increased echogenicity of the pericystic fat. Although concurrent bacterial cystitis may also be considered with such pericystic ultrasonographic abnormalities, we found a low rate of positive urine cultures in our population relative to the cats with these changes, and no statistically significant association of these ultrasound findings with a positive urine culture. The nature of these pericystic changes was not determined since fluid samples were not analyzed due to the low level of concern for urinary rupture. Some sources mention the possibility of transudation of urine through a severely inflamed bladder wall,[25,26] but other possible explanations would include an aseptic inflammatory effusion due to severe acute cystitis[27,28] secondary to urethral obstruction. Further studies may be performed to further characterize the nature of these pericystic changes, but our results suggest that they are common, and not associated with increased risk of reobstruction, prolonged hospitalization, or severity of azotemia or hyperkalemia. All urine cultures in this study were collected immediately following a newly placed urinary catheter. Although our rate of a positive urine culture was similar to prior reports,[6,29] contaminant growth exceeding the cutoff of 1000 cfu/ml could be possible, considering that the technique inherently has a greater risk for contamination than cystocentesis.[14]

Renomegaly, pyelectasia, and perirenal effusion were also common renal changes in our study. We defined significant pyelectasia based on a prior report where a pelvic diameter of >3.4 mm would be unlikely seen in cats with normal renal function or diuresis.[19] Perirenal effusion was associated with severe hyperkalemia. A possible explanation could be that this change is more likely associated with more severe or long standing episodes of obstruction and seen in more critically ill cats.[9,30] Perirenal effusion has been associated with acute kidney injury secondary to multiple etiologies and is theorized to represent an ultrafiltrate due to tubular backleak into the renal interstitium, which overwhelms lymphatic drainage, although urine leakage secondary to increased pressure is also theorized.[12]

Cystolithiasis was identified in 47% of cats, which is a larger number than identified in a prior report, in which 13/45 cats (28.9%) with urethral obstruction had cystolithiasis.[3] However, in that previous study, survey radiography was used in some cases to image the bladder, and the increased frequency in our study may in part be due to the higher sensitivity of ultrasound compared with survey radiography.[31,32] Another possible explanation is that our population was imaged following catheterization, which could have resulted in retropulsion of urethral calculi into the urinary bladder that would otherwise not be detected if evaluated prior to establishing urethral patency. This said, false-positive diagnosis of cystolithiasis may have happened in our study due to the potential ambiguity between cystoliths and conglomerates of mineralized sediment. Since the majority of cats with cystoliths were managed initially with dietary and medical management, most cats in our study did not undergo cystotomy, and therefore confirmation of ultrasound findings was not available. Due to the retrospective nature of the study, decision criteria to

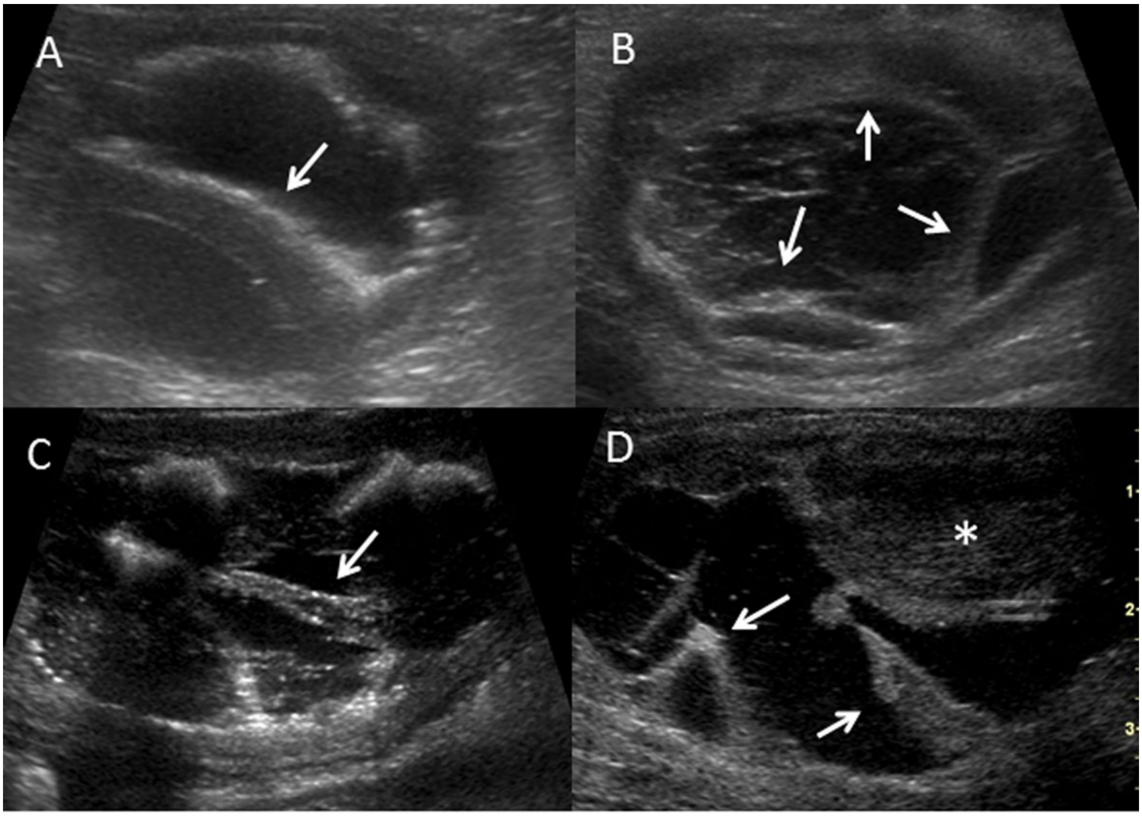

Fig. 3. Four ultrasound images (A–D) of four different cats with similar bladder ultrasound findings of thick echogenic septa (arrows) traversing the bladder lumen with a similar appearance to previously reported pseudomembranous cystitis. There is also a combination of bladder thickening, increased urine echogenicity, and hyperechoic sediment and small calculi. Image (D) also shows a large intramural thickening presumed to be an intramural hematoma (∗). The cat in image (D) was the only one of the four cats with these septa changes to reobstruct.

surgically or medically manage cats with uroliths was typically unclear. In addition to cystoliths, small ureteroliths were identified with ultrasound. For these cats, the maximum pyelectasia and pelvic asymmetry were all 3 mm or less, which was similar to the general population. In a prior report,[19] the mean pyelectasia diameter for cats with ureteral obstruction was 10.9 mm ± 10.8, and the mean pelvic diameter asymmetry was 6.9 mm ±.10.0, which was significantly larger than cats with other disorders. Also, in two of the three cats with ureteroliths in our study, the larger pelvic diameter was contralateral to the ureterolith. We feel the cats in our study unlikely had complete ureteral obstruction, however, partial obstruction cannot be excluded.

Four cats in the current study had ultrasonographic characteristics similar to previously reported pseudomembranous cystitis, with thick echogenic septa transecting the bladder lumen. In a case series of four cats with this condition, the bladder contents at surgery were fibrinous exudate, blood clots, and necrotic debris, and the bladder wall was thickened, hemorrhagic, and ulcerated. It was thought that the hyperechoic strips seen on ultrasound were due to sloughing of necrotic areas of the bladder wall into the bladder lumen.[23] The authors hypothesized that cystotomy may be helpful in these cases to help restore urine outflow. The four cats in our study were only medically managed, and the one cat that concurrently had a presumed large intramural hematoma was the only one of the cats to reobstruct within the follow-up period. While ultrasonographically very similar, it is not clear that our cats were affected by the same condition as previously reported since we did not obtain histopathologic confirmation. Additional evaluation of this condition would be necessary before clinical conclusions could be made.

Survival to discharge in the current study was 94.3%, which is similar to prior studies reporting episode survival rates of 91.1%,[3] 93.6%,[8] and 91.5%.[6] Recurrence of urethral obstruction was documented in 34.4% of cats within a 6-month period, which is similar to prior reports,[3,6,8,29] but higher than the 14.7% recurrence rate reported in another study.[10] Median duration to recurrent urethral obstruction in the current study was 7 days postdischarge (range 1–163 days) with 21.3% of cats reobstructing within the first 14 days following discharge. Other studies had a similar finding where most reobstructions occurred within 48 h of catheter removal,[29] and another study with a median time to reobstruction of 17 days (range 3–728 days).[3]

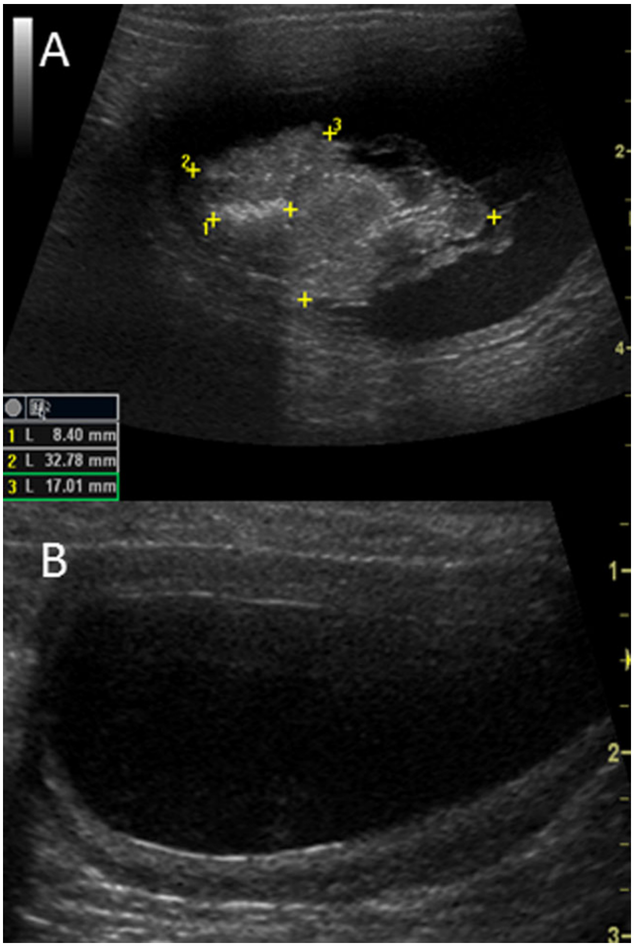

FIG. 4. Ultrasound images of the bladder from the same cat obtained 15 days apart. (A) First ultrasound examination showing a large, heterogeneous luminal mass. There are central hyperechoic foci, with a larger shadowing region between the first set of calipers (labeled "1"). (B) Second ultrasound of the bladder of the same cat as (A), 15 days later, showing resolution of the prior intraluminal mass.

There are other limitations to our study in addition to those already discussed. Ultrasound is not accepted as a gold standard for the evaluation of urolithiasis although, with improving ultrasonographic image quality and technology, this may be a paradigm shift as ultrasound has a similar sensitivity to double contrast cystography and an improved sensitivity with higher probe frequencies.[31–33] Ultrasound has a similar sensitivity compared with double contrast cystography but has the benefit of typically being performed in nonsedated patients, does not require ionizing radiation, or the introduction of contrast material into the urinary tract. Other limitations would include the retrospective and subjective assessment of several parameters. Due to the retrospective nature of the study and multiple ultrasound operators, acquisition parameters and imaging technique was not standardized across all cats, which may have affected image appearance in some cases decreasing the accuracy of ultrasound criteria assessment. Additionally, this report describes ultrasound findings following the establishment of urethral patency and catheterization, which may not completely reflect ultrasound findings in cats prior to relieving their obstruction. Another limitation is the variability in hospitalization treatment protocols, which could affect the significance of certain variables. In our hospital, many cats with bloody or turbid urine or those with a large amount of sediment observed via the collection system, urinalysis, or ultrasound routinely have their bladders flushed intermittently with sterile saline. This practice, which may not be standard in other hospitals, could have an effect on the significance of urine echogenicity or sediment seen on ultrasound and patient outcomes. We also utilized outcomes following discharge in which owner compliance to standard recommendations cannot be controlled or easily confirmed, which could potentially have affected some patient outcomes. The majority of cats ($n = 65$) included in this retrospective study were enrolled in a prior prospective blinded clinical trial evaluating an antispasmodic medication, which is still under manuscript preparation at the time this imaging study was prepared. The benefit of the prior study was that all cats presenting with urethral obstruction received a focal urinary ultrasound without bias of age, severity of illness, or history of recurrent FLUTD episodes, which would have all been potential downfalls of this retrospective study. A prospective evaluation of ultrasound findings following urethral obstruction in cats would aid in decreasing the limitations of the current study, which could include defined ultrasound parameters, the utilization of follow-up ultrasound changes over time, and a more detailed prospective client survey to include nonobstructive lower urinary tract signs, which were not addressed in our study.

In conclusion, ultrasound identified concurrent lesions with the urinary system following urethral obstruction in this group of cats. In addition to bladder wall thickening, urine sediment, renomegaly, and pyelectasia, we found a high prevalence of previously unreported findings including pericystic effusion and hyperechoic pericystic fat. We also observed several uncommon findings such as a possible intramural hematoma, large luminal blood clots, or suspected pseudomembranous cystitis, which could provide clinicians with information to guide patient management. Although the observed findings were not associated with reobstruction, severe azotemia, severe hyperkalemia, positive urine culture, or an extended length of hospitalization; it was found that perirenal effusion was associated with severe hyperkalemia. Authors propose that this ultrasound finding may be an indicator of more longstanding episodes of obstruction and more critically ill patients. This theory may warrant further investigation in future studies.

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