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Objective—To determine the effectiveness of cystotomy for complete removal of urocystoliths and urethroliths in dogs, the types and frequency of diagnostic imaging performed to verify complete urolith removal, the complications that develop as a result of cystotomy, and predictors of each of these variables.

Design—Retrospective case series.

Animals—128 dogs that underwent a cystotomy for removal of urocystoliths, urethroliths, or both from 1994 through 2006.

Procedures—The following data were obtained from medical records: sex, body weight, number and locations of lower urinary tract uroliths identified in preoperative and postoperative imaging reports, types of imaging used for urolith detection, number of uroliths recovered during cystotomy, quantitative urolith composition, and major complications attributable to cystotomy. Objective criteria were applied to determine whether a cystotomy failed or succeeded and whether appropriate imaging was performed. Associations between potential prognostic factors and outcomes were statistically assessed.

Results—Effectiveness of cystotomy could be determined in 44 (34%) dogs, of which 9 (20%) had incomplete removal of uroliths. Appropriate postoperative imaging was performed for only 19 (15%) dogs, of which 8 had incomplete removal. Dogs with both uroliths and urocystoliths were more likely to have a failed cystotomy than dogs with only urethroliths or urocystoliths. Complications developed in 5 (4%) dogs.

Conclusions and Clinical Relevance—Cystotomy was a safe and effective surgical procedure for removal of lower urinary tract uroliths in most dogs. Failure to remove all uroliths occurred in a substantial percentage of patients. (J Am Vet Med Assoc 2010;236:763–766)

In dogs, uroliths can develop in the bladder or urethra.1 Methods to eliminate uroliths (urocystoliths, urethroliths, or both) in the lower urinary tract (bladder and urethra) include dissolution and removal via surgical and nonsurgical techniques or laser lithotripsy.2–12 Diagnostic imaging before and after treatment is recommended to assess the completeness of urolith removal, particularly when multiple uroliths are present or the number removed is less than the number detected prior to treatment. Double-contrast cystography is more sensitive than plain radiography, pneumocystography, and ultrasonography for detection and enumeration of canine urocystoliths.13 To the authors’ knowledge, no studies have been performed to determine the optimal technique for imaging urethroliths in dogs.

Intracorporeal lithotripsy was recently introduced as a means of removing lower urinary tract uroliths in dogs.2,14–16 A single attempt of holmium:yttrium-aluminum-garnet (Ho:YAG) laser lithotripsy fails to result in removal of lower urinary tract uroliths in 22% to 24% of dogs in which this method is used.2,14,15,17 When the same procedure is used but is performed with an electrohydraulic lithotripter, the failure rate is 81%.16 Although cystotomy has been used for a substantially longer period than lithotripsy, there exists only 1 abstract17 regarding the efficacy of cystotomy for complete removal of urocystoliths in dogs. Following cystotomy in the associated studies, radiographically detectable uroliths remained in 14% to 20% of dogs.

The purpose of the study reported here was to determine the effectiveness of cystotomy for complete removal of urocystoliths and urethroliths in dogs, the types and frequency of diagnostic imaging to verify complete urolith removal, the complications that developed as a result of cystotomy, and predictors of each of these variables.

Materials and Methods

Case selection—Medical records of the Virginia-Maryland Regional College of Veterinary Medicine were searched for dogs that had undergone a cystotomy from 1994 through 2006 for removal of urocystoliths, urethroliths (in combination with urethral catheterization or retrograde urohydropropulsion), or both. These records included only dogs managed after the year of the initial report of cystotomy efficacy.1 (1994).

Medical records review—The following data were extracted from the medical records: sex, body weight,
number and locations of lower urinary tract uroliths identified in preoperative and postoperative imaging reports, types of imaging used for urolith detection, number of uroliths recovered during cystotomy, quantitative urolith composition (determined at a diagnostic laboratory), and major complications attributable to cystotomy (eg, incisional abnormalities, uroabdomen, urethral obstruction, or septic peritonitis). A successful cystotomy was defined as one after which no uroliths were detected via appropriate imaging or one in which the number of uroliths recovered during cystotomy equaled the number identified by preoperative imaging. A failed cystotomy was defined as one after which uroliths were still detected via appropriate imaging. All other cystotomies were classified as unknown outcome.

Appropriate imaging for urocystolith detection was defined as plain radiography for urocystoliths with a low false-negative detection rate (magnesium ammonium phosphate, calcium oxalate, mixed-composition, and compound uroliths) or ultrasonographic or double-contrast cystography for any urolith type. Appropriate imaging for urethroliths was defined as plain radiography for magnesium ammonium phosphate, calcium oxalate, mixed-composition, and compound uroliths or positive contrast urethrography for any urolith type. No dogs were identified in which other imaging modalities were used for detection of lower urinary tract uroliths. Postoperative imaging was only considered appropriate if obtained within 14 days after cystotomy.

Statistical analysis—Statistical software was used to perform all analyses. Medians and ranges were determined for the continuous variable body weight. Contingency tables were generated for the following categorical variables: dog sex (males vs female) and breed, type of surgeon (faculty, resident, or intern), and urolith category (urate [sodium acid urate and ammonium urate] or nonurate [magnesium ammonium phosphate, calcium oxalate, calcium phosphate, mixed composition, or compound]). Subsequent statistical analysis focused on identifying factors associated with 3 outcome variables: performance of appropriate postoperative imaging, cystotomy failure, and development of postcystotomy complications. For each of the 3 outcome variables, the putative prognostic factors considered included body weight, breed, sex, presence of urethroliths before cystotomy, presence of urocystoliths after cystotomy, presence of urethroliths versus urocystoliths before cystotomy, presence of both urethroliths and urocystoliths versus either urethroliths or urocystoliths before cystotomy, and type of surgeon. Additionally, presence after cystotomy of urethroliths, urocystoliths, both urethroliths and urocystoliths, urethroliths versus urocystoliths, and both urethroliths and urocystoliths versus either urethroliths or urocystoliths was considered as a potential predictor of complications.

Associations between body weight and each outcome variable were assessed by use of the Wilcoxon rank sum test, and associations between each of the categorical predictor variables and the outcome variables were tested by use of the Fisher exact test. Body weight, sex, urolith category, presence before cystotomy of both urethroliths and urocystoliths versus either urethroliths or urocystoliths, and type of surgeon were evaluated in a multivariable logistic regression model, with the outcomes of performance (vs nonperformance) of appropriate postoperative imaging and success (vs failure) of cystotomy. For dogs in which cystotomy was performed twice because of incomplete urolith removal the first time, only data for the first cystotomy were included. The multivariable model for predicting development of complications after cystotomy included only body weight, sex, and urolith category. Some variables were excluded from each of the multivariable models because some cells in contingency tables included 0 counts, leading to quasiparallel of the observations. A value of P < 0.05 was considered significant for all analyses.

Results

Records of 132 dogs were identified, 4 of which were excluded because they were missing all required information (2 dogs with urethroliths and 2 with urocystoliths). Therefore, data from 128 dogs with 133 cystotomies were included in the analysis. Cystotomy was performed a second time in 7 dogs because uroliths were incompletely removed during the first cystotomy. In all, 37 breeds were represented, including mixed breed. Effectiveness of the cystotomy could be assessed for 44 (34%) dogs, in which 9 (20%) procedures resulted in failure to remove all uroliths. In 19 (15%) dogs, appropriate postoperative imaging was performed; in the remainder (n = 109 [85%]), it was not. Of the 19 dogs with appropriate postoperative imaging, 8 (42%) cystotomies resulted in failure to remove all uroliths. In 25 dogs, cystotomy was deemed successful because the number of uroliths recovered matched the number observed via preoperative imaging, and in 10 of these dogs, postoperative imaging verified complete removal. Of the 9 dogs in which the procedure failed, all had at least 1 urocystolith and 5 (4 male and 1 female) had concurrent urethroliths detected via preoperative imaging. One dog in which only urocystoliths were identified before cystotomy had a urethrolith detected on postoperative images. Follow-up procedures to remove remaining uroliths were performed in 8 dogs and included repeated cystotomy (n = 4), cystoscopic basket retrieval (1), fluoroscopic basket retrieval (1), urethrotomy (1), and urethrolith removal by crushing it with digital transrectal palpation and massaging it out of the urethra (1). Complications attributable to the cystotomy developed in 5 (4%) dogs, including a seroma (n = 2), cutaneous suture reaction (1), excessive cutaneous incision swelling (1), and cutaneous incision dehiscence (1). Because few dogs in the study received a follow-up examination at our institution, for most dogs, only complications that developed during hospitalization or those reported via telephone conversations with the owners or referring veterinarians were included.

Appropriate postoperative imaging—Appropriate postoperative imaging was performed for only 19 (15%) dogs, of which 8 had incomplete removal. Appropriate postoperative imaging was performed significantly (P = 0.011) more often in dogs that had nonurate uroliths (17/80 [21%]) than in dogs that had urate uroliths (1/36 [3%]). The median body weight for dogs...
that received appropriate postoperative imaging (8.0 kg [17.6 lb]; range, 3.9 to 26.7 kg [8.6 to 58.7 lb]) was not significantly ($P = 0.673$) different from the median body weight for dogs that did not receive appropriate postoperative imaging (8.0 kg; range, 1.2 to 42.0 kg [2.6 to 92.4 lb]). None of the other predictor variables analyzed were significantly associated with appropriate postoperative imaging. Similarly, multivariable logistic regression revealed that dogs with nonurate uroliths were more likely to receive appropriate postoperative imaging than those with urate uroliths (odds ratio, 8.6; 95% confidence interval, 1.0 to 71.7; $P = 0.047$). Body weight, sex, and type of surgeon were not associated with appropriate postoperative imaging in that model.

**Failed cystotomy**—The proportion of dogs with a failed cystotomy was greater ($P = 0.006$) in dogs that had both urethroliths and urocystoliths identified before cystotomy (8/38) than in dogs that had either urethroliths or urocystoliths (4/36). The median body weight for dogs with a failed cystotomy (7.0 kg [15.4 lb]; range, 3.9 to 26.7 kg [8.6 to 58.7 lb]) was not significantly ($P = 0.675$) different from the median body weight for dogs with a successful cystotomy (7.1 kg [15.6 lb]; range, 2.0 to 30.5 kg [4.4 to 67.1 lb]). None of the other predictor variables were significantly associated with cystotomy failure. Similarly, multivariable logistic regression revealed that dogs with both urethroliths and urocystoliths identified before cystotomy were significantly ($P = 0.009$) more likely to have a failed operation than dogs that had either urethroliths or urocystoliths (odds ratio, 12.1; 95% confidence interval, 2.4 to 418.3). Body weight, sex, urolith category, and type of surgeon were not associated with failure of cystotomy in the multivariable model.

**Development of postoperative complications**—Postoperative complications developed in 5 (4%) dogs. The median body weight for dogs that developed a complication (5.8 kg [12.8 lb]; range, 3.5 to 8.7 kg [12.1 to 19.1 lb]) was not significantly ($P = 0.226$) different from the median body weight for dogs without complications (8.0 kg; range 1.2 to 42.0 kg). None of the other predictor variables analyzed were significantly associated with postoperative complications. Similarly, multivariable logistic regression revealed that body weight, sex, and urolith category were not associated with development of postoperative complications.

**Discussion**

The present study was performed to determine the effectiveness of cystotomy for complete removal of lower urinary tract uroliths in dogs. The procedure failed to result in complete removal of urocystoliths, urethroliths, or both in 20% of dogs in which that effectiveness could be assessed and in 42% of dogs in which postoperative imaging was used to make this assessment. The proportion of dogs with a failed cystotomy was higher than the 14% that had failed removal of urocystoliths in another retrospective study but similar to results of a more recent retrospective study in which 20% of dogs had a failed cystotomy.

The effectiveness of cystotomy could be determined in only 34% of dogs in the present study (via counts of retrieved uroliths or postoperative imaging), and in only 15% of all dogs was this effectiveness evaluated by use of appropriate diagnostic imaging techniques. In another study, 56% of dogs underwent postoperative imaging. The low proportion of dogs that underwent postoperative imaging is an important limitation of that study and ours. Clearly, if all dogs received appropriate postoperative imaging, then the proportion deemed to have a failed cystotomy might change. Double-contrast cystography is the optimal technique for detection of urocystoliths, particularly tiny uroliths, and if it had been performed in all dogs in the present study, the proportion of dogs identified as having a failed cystotomy would likely have been higher. However, in the authors’ opinion, results of the present study are likely representative of what could be expected in routine veterinary practice, in which some veterinarians do not obtain radiographs following cystotomy and many do not perform double-contrast cystography or urethrograms on all dogs afterward.

We found that appropriate postoperative imaging, which usually consisted of plain radiography (data not shown), was more likely to be performed in dogs with magnesium ammonium phosphate, calcium oxalate, mixed-composition, and compound uroliths, which are all typically radiopaque. Contrast radiography is more time-consuming than plain radiography, which might explain why contrast radiography was not used more often. Another consideration is that postoperative imaging was not performed when surgeons were confident of complete removal, and if indeed their patients had imaging performed and the cystotomies were successful, the overall proportion of dogs with a failed cystotomy would have been lower. At our institution, it is common practice to intraoperatively catheterize and flush the urethra in both a normograde and retrograde direction with the largest diameter catheter that will freely pass the entire length of the urethra to ensure all urethroliths are removed. We could not verify this was done in all dogs in the present study, but assuming catheterization was successful, it is likely the surgeons assumed all urethroliths had been removed and therefore may not have obtained postoperative radiographs. Similarly, surgeons may have been more inclined to perform postoperative imaging when they were not confident of complete removal; thus, the proportion of dogs with a failed cystotomy may be falsely inflated.

It is important to mention that we included dogs in which a cystotomy was performed in combination with urethral catheterization, retrograde urohydropropulsion, or both for removal of urethroliths. We did this because this is a common approach to removing urethroliths, particularly in dogs that concurrently have urocystoliths. Dogs with urethroliths were included in 1 of the 2 aforementioned previous studies, but whether they were included in the other study was not reported. The presence of urethroliths in combination with urocystoliths significantly increased the odds of cystotomy failure in our study. Urethroliths were detected via postoperative imaging in approximately half (5/9) of the dogs with a failed procedure. For most of those dogs, failure appeared to have occurred because urethroliths were not effectively moved up into the bladder and not because the cystotomy failed. Performing retro-
grade hydropropulsion of urethroliths prior to cystotomy and verifying their new location in the bladder may help circumvent this type of failure. In the fifth dog, a urocystolith must have been unknowingly advanced into the urethra, leading to failure of the procedure.

A limitation of the retrospective nature of our study is that the reasons appropriate postoperative imaging was not performed could not be determined. One dog likely did not undergo postoperative imaging because it was euthanized during or immediately after cystotomy in response to the poor prognosis associated with acquired portosystemic shunts found during the same surgery. Another important difference between this study and a prospective case series is that we defined appropriate postoperative imaging on the basis of the known composition of uroliths, a key factor that may not be known at the time of cystotomy. Although urolith composition can be estimated with fair accuracy from radiographic characteristics or patient signalment, in some situations, surgeons may inaccurately predict urolith type. For example, some dogs with urate uroliths in the present study were diagnosed prior to cystotomy by means of ultrasonography but underwent plain radiography after cystotomy, perhaps because the surgeon failed to correctly predict the uroliths were urates, which are commonly radiolucent. We did not record all concurrent diseases but did notice that a large number of dogs underwent concurrent cystotomy and surgery to diagnose or correct a portosystemic shunt; most had urate uroliths. Those dogs rarely underwent postoperative imaging, and when they did, it consisted of a portogram, which could not be used to rule out urate uroliths.

Our categorization of uroliths for plain radiographic detection was not perfect and is a limitation of this study. We considered magnesium ammonium phosphate, calcium oxalate, mixed-composition, and compound uroliths likely to be detected via plain radiography and urate uroliths as unlikely to be detected, but this is not always the situation. Additionally, to determine cystotomy success in 25 dogs, we compared the number of uroliths counted on diagnostic images with the number recovered. Although this is a common method for determining completeness of urolith removal, it can be difficult to accurately enumerate uroliths by use of radiographs or ultrasonograms. We did not retrospectively review all radiographs and ultrasonograms to ensure they included the entire urinary tract (ie, the full urethral length) and assess urolith characteristics. In many situations, the images had been destroyed, and we believed another review of the existing images would not necessarily yield more accurate results than those from the original interpreter.

Results of studies performed to evaluate the effectiveness of various procedures in removing lower urinary tract uroliths from dogs cannot be directly compared with each other or with the results reported here. Differences in urolith burden, size, number, and numerous other factors likely exist between these studies. In studies involving laser lithotripsy, diagnostic imaging was performed before and after surgery for all subjects, likely yielding a more accurate assessment of method effectiveness than our retrospective study. However, even with the most effective methods of urolith removal, the possibility of failure exists. Therefore, veterinarians should seriously consider performing diagnostic imaging after urolith removal. In fact, failure to perform radiography following cystotomy is considered by some veterinarians to represent a failure in the standard of care. In the study reported here, cystotomy appeared to be a safe and effective surgical procedure for removal of lower urinary tract uroliths in most dogs, with only few, minor postoperative complications. Results emphasize the importance of performing appropriate postoperative imaging to verify the completeness of urolith removal.

References