Comparison of laser lithotripsy and cystotomy for the management of dogs with urolithiasis

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Objective—To compare efficacy, required resources, and perioperative complications between laser lithotripsy and cystotomy for urolith (ie, urocystoliths and urethroliths) removal in dogs.

Design—Retrospective case-control study.

Animals—66 dogs with urolithiasis treated by laser lithotripsy (case dogs) and 66 dogs with urolithiasis treated by cystotomy (control dogs).

Procedures—Medical records were reviewed. Complete urolith removal rate, resources (ie, duration of hospitalization, procedure time, anesthesia time, procedure cost, and anesthesia cost), and complications (ie, hypotension, hypothermia, incomplete urolith removal, and requirement of an ancillary procedure) were compared between cystotomy group dogs and lithotripsy group dogs.

Results—Duration of hospitalization was significantly shorter for lithotripsy group dogs, compared with cystotomy group dogs. Procedure time was significantly shorter for cystotomy group dogs, compared with lithotripsy group dogs. Cost of anesthesia was significantly less for cystotomy group dogs, compared with lithotripsy group dogs. No significant differences were found between cystotomy group dogs and lithotripsy group dogs with regard to urolith removal rate, procedure cost, anesthesia time, or any of the evaluated complications.

Conclusions and Clinical Relevance—Laser lithotripsy is a minimally invasive procedure that has been shown to be safe and effective in the removal of urocystoliths and urethroliths in dogs. No significant differences were found in the required resources or complications associated with laser lithotripsy, compared with cystotomy, for removal of uroliths from the lower portions of the urinary tract of dogs. Laser lithotripsy is a suitable, minimally invasive alternative to surgical removal of urethroliths and urocystoliths in dogs. (J Am Vet Med Assoc 2009;234:1286–1294)

Cystotomy remains one of the most common methods of removing uroliths from the urinary bladders of dogs. This technique is often selected because it is easy to perform with few complications. To avoid urethral surgery, urethroliths can also be removed through a cystotomy incision following repositioning of calculi via retrograde urohydropropulsion. Although the standard of care for rapid removal of uroliths from the lower portion of the urinary tract is surgery, additional minimally invasive methods of urolith removal have been recently proposed for dogs.1–7,a

Endoscopic laser lithotripsy is recognized as the standard of care for managing human ureteroliths, urocystoliths, and urethroliths with reported success rates of >90%.1–6 Endoscopic laser lithotripsy has also been used to treat urocystoliths and urethroliths in horses, cattle, goats, and pigs with variable success rates.17–20 In a preclinical study in dogs, Davidson et al2 showed that laser lithotripsy by use of an Ho:YAG laser was successful in fragmenting uroliths in the urethra of males with minimal short-term complications.

In contrast to surgical urolith removal, endoscopic laser lithotripsy permits access to the entire lower portion of the urinary tract without incising the bladder or urethra. Although the minimally invasive nature of endoscopic laser lithotripsy would potentially avoid complications associated with surgical manipulation of tissue, such procedures are often associated with increased procedure time and need for specialized equipment and training. The purpose of the study reported here was to determine whether laser lithotripsy is a suitable alternative to cystotomy for removal of uroliths in dogs by comparing effectiveness, resources, and perioperative complications between these 2 procedures.

Abbreviation

Ho:YAG Holmium:yttrium-aluminum-garnet

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Compared with laser lithotripsy, it was hypothesized that cystotomy is a more effective procedure that can be completed in less time.

**Materials and Methods**

This study was designed as a retrospective case-control study.

**Case selection**—Medical records of the Veterinary Medical Center at the University of Minnesota were searched to identify dogs that underwent laser lithotripsy for urolith fragmentation and removal (ie, lithotripsy group dogs) between October 1, 2004, and October 31, 2006. During this period, laser lithotripsy was only performed to manage dogs with urocystoliths or urotheloliths. Dogs were included if uroliths were too large to be spontaneously voided (typically urocystoliths ≥ 4 mm in diameter in males and ≥ 5 mm in diameter in females) or if urotheloliths were associated with partial or complete urethral obstruction. Dogs were not excluded on the basis of the number of uroliths present. Dogs were excluded from evaluation if they had evidence of active untreated urinary tract infection, urinary neoplasia, a clotting disorder resulting in a tendency to bleed, or diseases likely to increase the risk of adverse events associated with anesthesia. Dogs were also excluded if they had a urethral diameter that prohibited passage of the cystoscope. Thus, males with a body weight of < 5 kg (11 lb) and females with a body weight of < 4.5 kg (9.9 lb) were excluded. To determine eligibility, the following information was reviewed: history and physical examination findings; results of serum biochemical analysis, urinalysis, urine bacterial culture, and CBC determinations; and findings on survey abdominal radiographs.

**Control selection**—Control dogs consisted of dogs that underwent cystotomy (ie, cystotomy group dogs) for urolith removal at the same institution as lithotripsy group dogs and during the same period. Cystotomy group dogs were selected to match the sex, urolith composition, body weight, urolith volume and number, and urolith location of lithotripsy group dogs. A match was considered appropriate if sex and urolith type were identical, difference in body weight was within 8 kg (17.6 lb) for dogs weighing > 10 kg (22 lb) and within 1 kg (2.2 lb) for dogs weighing ≤ 10 kg, urolith volume and number were radiographically similar, and urolith location was the same in at least 1 anatomic region (bladder or urethra). Data on cystotomy group dogs were originally retrieved from hospital admissions records during the same period as lithotripsy group dogs. However, because of insufficient matches, data on cystotomy group dogs were also selected from admissions records between October 1994 and May 2007.

**Data collection**—Data tabulated from each record included: signalment; body weight; urolith composition, number, volume, and location; type of procedure performed to remove uroliths; procedure and anesthesia times; presence of hypotension and hypothermia during anesthesia; complete and incomplete urolith removal rates; ancillary procedures performed to complete urolith removal; anesthetic and procedure costs; and duration of hospitalization.

Uroliths were classified on the basis of results of quantitative mineral analysis. Because most uroliths were calcium oxalate, uroliths were categorized as calcium oxalate uroliths or other type of urolith (ie, calcium phosphate, cystine, silica, struvite, and urate).

Complete urolith removal was defined as no radiographic evidence of uroliths in either the bladder or urethra immediately following each procedure. In dogs with incomplete urolith removal, the remaining uroliths were measured from radiographs with a ruler and were classified into 3 groups on the basis of the longest dimension (ie, greatest diameter) of the largest remaining urolith: < 1 mm in diameter, 1 mm to < 3 mm in diameter, or ≥ 3 mm in diameter. Any dog with uroliths ≥ 3 mm in diameter was categorized as a treatment failure.

The duration of hospitalization was defined as the time (in days) from the day of the procedure to the day of hospital discharge. Any procedure performed in addition to the initial lithotripsy or cystotomy to aid in urolith removal (including a repeat procedure) was considered an ancillary procedure. Anesthesia time was defined as the time from induction of anesthesia to the time of cessation of administration of all anesthetic agents. Procedure time for cystotomy was defined as the time on the anesthetic record between the marked cystotomy procedure start and end times. Procedure time for laser lithotripsy was defined as the time from initial placement of the cystoscope into the urethra to the time of removal of the cystoscope following the last evaluation of the urinary tract. Times for ancillary procedures in both groups were not included in the procedure time.

Procedure and anesthetic costs were calculated for each dog. Any cost directly related to the treatment procedure and immediate postoperative care was included in the procedure cost. Any preoperative and postoperative costs associated with antimicrobials or analgesics, hematologic and serum biochemical analyses, urinalyses, bacterial cultures, Elizabethan collars, and diagnostic imaging were excluded because of the variability among dogs. Cost comparisons were limited to paired lithotripsy group dogs and cystotomy group dogs evaluated after January 1, 2004, as a result of inconsistent documentation of costs prior to 2004. To achieve the most accurate cost comparison, a list of the costs incurred by each dog in both groups was recorded and then recalculated on the basis of the current hospital costs. These values were then used to compare cost between cystotomy group dogs and lithotripsy group dogs.

Major (ie, death, wound dehiscence, urethral obstruction, bladder rupture, and urethral perforation) and minor (ie, hypothermia and hypotension) perioperative complications were recorded for each group. Hypotension was defined as a systolic blood pressure of < 90 mm Hg that persisted for > 10 minutes. Hypothermia was defined as a body temperature of < 37.2°C (99°F) that persisted for > 10 minutes.

**Radiography**—Preoperative and postoperative survey radiography delineating the entire lower portion of the urinary tract was performed in all dogs. In many instances, images from contrast cystography were also...
Lithotripsy was performed in dogs to retrieve uroliths. If retrograde urohydropropulsion did not succeed, a cystotomy was performed preoperatively, intraoperatively, or both in all dogs by use of a red rubber catheter and sterile saline solution was flushed through the working channel during fragmentation. Once fragments were subjectively assessed to be small enough to pass easily through the urethra, they were either retrieved with a urolith-retrieving basket or voided via urohydropropulsion. The bladder and urethra were then endoscopically reevaluated for presence of urolith fragments. Survey radiography and double-contrast cystography were used to assess completeness of urolith removal. Following anesthetic recovery, each dog received a single dose of meloxicam (0.2 mg/kg, IV).

Statistical analysis—Comparisons were performed as a matched pair analysis. A Student paired $t$ test was used for the comparison of continuous variables. A McNemar test was used for the comparison of dichotomous variables. If a variable was not available for the analysis, the corresponding variable from its match in the opposite group was also excluded.

A comparison of groups separated by sex was performed in a similar fashion as the initial analysis, as was a comparison of procedure time in dogs with complete urolith removal only. Standard statistical software was used for all analyses. For all comparisons, a value of $P < 0.05$ was considered significant.

Results

Between October of 2004 and October of 2006, 67 dogs underwent laser lithotripsy to manage urolithiasis. The records of 319 dogs that underwent cystotomy between October 1994 and May 2007 were reviewed to identify suitable matches. One lithotripsy group dog could not be matched appropriately with a cystotomy group dog of similar sex and urolith composition.
Therefore, data from this lithotripsy group dog were excluded from the study. Thus, 66 dogs in each group satisfied the inclusion criteria.

There were 39 males and 27 females in each group. There were 1 sexually intact female and 2 sexually intact male lithotripsy group dogs. The rest of the dogs were spayed or castrated. In the lithotripsy group, 46 dogs had urocystoliths, 9 had urethroliths, and 11 had urocystoliths and urethroliths. In the cystotomy group, 42 dogs had urocystoliths, 4 had urethroliths, and 20 had urocystoliths and urethroliths. In each group, 50 dogs had calcium oxalate uroliths and 16 dogs had uroliths classified as other.

For cystotomy group dogs and lithotripsy group dogs, the median age was 7.5 years (range, 1.5 to 15.2 years) and 7.8 years (range, 0.3 to 13.0 years), respectively; the median body weight was 7.8 kg (17.2 lb; range, 3.0 to 39.1 kg [6.6 to 86.0 lb]) and 9.0 kg (19.8 lb; range, 4.5 to 40.8 kg [9.9 to 88.9 lb]), respectively; and the median urolith volume was 1.08 cm$^3$ (range, 0.01 to 38.68 cm$^3$) and 0.92 cm$^3$ (range, 0.02 to 41.63 cm$^3$), respectively.

Urolith removal—Complete urolith removal rate was not significantly different between cystotomy group dogs (53/66 [80%]) and lithotripsy group dogs (51/66 [77%]). If treatment failure was defined as the incomplete removal of uroliths ≥ 3 mm in diameter, both methods were again considered equally effective because there was no significant difference in success rate between cystotomy group dogs (57/66 [86%]) and lithotripsy group dogs (59/66 [89%]).

Incomplete urolith removal was detected in 15 lithotripsy group dogs and was defined on the basis of the longest dimension (ie, greatest diameter) of the largest remaining urolith. Seven of the 15 lithotripsy group dogs had uroliths ≥ 3 mm in diameter, 5 had uroliths 1 to < 3 mm in diameter, and 3 had uroliths < 1 mm in diameter. Nine of the 15 dogs were male, and 6 were female. Incomplete urolith removal was detected in 13 cystotomy group dogs. Nine of the 13 cystotomy group dogs had uroliths ≥ 3 mm in diameter, 3 had uroliths 1 to < 3 mm in diameter, and 1 had uroliths < 1 mm in diameter. Eleven of the 13 dogs were male, and 2 were female. For all 4 dogs with fragments < 1 mm in diameter, double-contrast cystography was performed after surgery.

Ancillary procedures to complete urolith removal were tabulated for each group. These procedures were performed in dogs of either group if urolith fragments ≥ 3 mm in diameter were not completely removed. In the lithotripsy group dogs, 7 ancillary procedures were performed in 7 dogs when urolith fragments ≥ 3 mm in diameter remained in the urinary bladder following initial lithotripsy. All 7 dogs weighed < 11 kg (< 24.2 lb; range, 4.8 to 11 kg [10.6 to 24.2 lb]). Four of the dogs had urocystoliths, and 3 had urethroliths and urocystoliths. Five males had a cystotomy immediately following unsuccessful lithotripsy. One male had a successful repeat lithotripsy 3 months after the first lithotripsy. One female with urolith fragments composed of magnesium ammonium phosphate underwent successful urolith dissolution with diet and treatment with antimicrobials. In the remaining 8 dogs with uroliths < 3 mm in diameter, no further attempts were made to remove or monitor the remaining fragments, and the final outcome of these dogs could not be determined within the limits of this study.

In cystotomy group dogs, 9 ancillary procedures were performed in 9 dogs. Seven of the 9 dogs were male. All 9 dogs weighed < 9 kg (range, 4 to 8.6 kg [8.8 to 18.9 lb]) and had multiple variably sized urocystoliths; 7 dogs also had urethroliths. In 5 of 9 dogs in which uroliths ≥ 3 mm in diameter remained in the urinary bladder following the initial cystotomy, complete removal was accomplished following repeat cystotomy. One of these 5 dogs required 3 cystotomies to achieve complete urolith removal. In the other 4 dogs in which remaining uroliths were > 3 mm, 4 additional ancillary procedures were performed, including 2 urethrotomies to retrieve urethroliths, 1 episiotomy to dislodge a urethrolith, and 1 scrotal urethrostomy to allow urine to bypass a urethrolith that remained in the distal portion of the urethra. In the remaining 4 dogs with incomplete removal, the remaining uroliths were < 3 mm in diameter. Attempts to eradicate the uroliths in these 4 dogs were not performed, and the final outcome of these dogs could not be determined within the limits of this study.

Resources—Procedure time and cost, anesthetic time and cost, and duration of hospitalization were compared between cystotomy group dogs and lithotripsy group dogs (Table 1). Compared with cystotomy, laser lithotripsy required significantly ($P = 0.012$) more time. On average, lithotripsy group dogs underwent an additional 23 minutes of procedure time, compared with cystotomy group dogs. Procedure time was not significantly different between cystotomy group dogs and lithotripsy group dogs when dogs with unsuccessful results (ie, dogs in either group with incomplete urolith removal; $n = 41$) were excluded from the analysis (lithotripsy group dogs, 76 ± 69 minutes; cystotomy group dogs, 58 ± 24 minutes; $P = 0.14$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of dog pairs evaluated</th>
<th>Lithotripsy group</th>
<th>Cystotomy group</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of hospitalization (d)</td>
<td>60</td>
<td>0.65 ± 0.23</td>
<td>1.17 ± 0.67</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Procedure time (min)</td>
<td>57</td>
<td>88 ± 62</td>
<td>83 ± 30</td>
<td>0.012</td>
</tr>
<tr>
<td>Procedure cost ($)</td>
<td>39</td>
<td>153</td>
<td>139</td>
<td>0.24</td>
</tr>
<tr>
<td>Anesthesia time (min)</td>
<td>37</td>
<td>783.14 ± 110.89</td>
<td>802.95 ± 181.93</td>
<td>0.78</td>
</tr>
<tr>
<td>Anesthesia cost ($)</td>
<td>37</td>
<td>432.46 ± 130.78</td>
<td>367.41 ± 28.80</td>
<td>0.005</td>
</tr>
</tbody>
</table>
The cost for managing uroliths with lithotripsy was not significantly different from procedure cost associated with cystotomy (Table 1). The analysis did not include all 66 pairs of dogs. For procedure cost, 27 dogs were removed from the analysis. In the lithotripsy group dogs, 5 dogs were removed because a cystotomy was performed immediately following a failed lithotripsy, resulting in incomplete costs incurred for the lithotripsy procedure. Twenty-two cystotomy group dogs were also excluded from the cost analysis because procedures were performed prior to 2004.

Anesthetic time for managing uroliths with lithotripsy was not significantly different from cystotomy (Table 1). Analyses did not include all 66 pairs of dogs. Nine dogs were removed from the analysis. Of lithotripsy group dogs, 1 was removed because time was not recorded and 5 were removed because a cystotomy was performed immediately following a failed lithotripsy, resulting in shared anesthesia resources. Of cystotomy group dogs, 1 was removed because time was not recorded and 2 were removed because a failed lithotripsy was performed immediately prior to the cystotomy, resulting in shared anesthesia resources.

Anesthetic cost was significantly less for cystotomy group dogs (Table 1). Analyses did not include all 66 pairs of dogs. Twenty-nine dogs were removed from the analysis. Of lithotripsy group dogs, 5 were removed because a cystotomy was performed immediately following a failed lithotripsy, resulting in shared anesthesia resources. Of cystotomy group dogs, 2 dogs were removed because a failed lithotripsy was performed immediately prior to the cystotomy, resulting in shared anesthesia resources. Twenty-two cystotomy group dogs were also excluded from the cost analysis because procedures were performed prior to 2004.

Duration of hospitalization for lithotripsy group dogs was significantly (P < 0.001) shorter than for cystotomy group dogs (Table 1). Six lithotripsy group dogs were excluded from the analysis. Five of the 6 dogs had a cystotomy performed immediately following the lithotripsy because of incomplete urolith removal, and 1 dog was boarded for nonmedical reasons following successful urolith removal.

Complications—Wound dehiscence, death, bladder rupture, and urethral perforation did not occur in any dog in either group. However, 1 dog developed acute urinary obstruction 1 day after lithotripsy. Complete urolith removal was achieved after the first lithotripsy. Cystoscopy was performed, and a blood clot was successfully removed from the urethra with a urolith retrieval basket. The dog had no further problems.

Minor perioperative complications (ie, hypotension and hypothermia) occurred in both groups (Table 2). For hypotension, 6 dogs were removed from the analysis. Of cystotomy group dogs, 1 was removed because blood pressure was not recorded and 4 were removed because a failed lithotripsy was performed immediately prior to the cystotomy. Of lithotripsy group dogs, 1 was removed because blood pressure was not recorded. For hypothermia, 8 cystotomy group dogs were removed from the analysis; 4 were removed because a failed lithotripsy was performed immediately prior to the cystotomy, and 4 were removed because body temperature was not recorded. The rate of minor complications was not significantly different between cystotomy group dogs and lithotripsy group dogs.

Sex—Because ancillary procedures and incomplete removal appeared to predominate in males, each group was separated on the basis of sex and the comparison of the required resources, urolith removal, and complications was repeated.

For resources, there was no difference in procedure cost and anesthesia time for males and females in either group. Both male and female lithotripsy group dogs had a significantly shorter duration of hospitalization, compared with male and female cystotomy group dogs. Procedure time for female cystotomy group dogs remained significantly shorter than for female lithotripsy group dogs. There was no significant difference in procedure time for males between groups. For anesthesia cost, there was no significant difference for females between groups, but cost was significantly less for male cystotomy group dogs, compared with female cystotomy group dogs.

Statistical analysis of incomplete urolith removal, the need for ancillary procedures, hypothermia, and hypotension on the basis of sex could not be performed because of the small sample size when groups were separated and the low frequency in which these variables occurred in each group.

Discussion

Cystotomy has remained the most common method of urolith removal in dogs. However, results of this study indicate that laser lithotripsy is an effective, safe comparable alternative. Although lithotripsy was associated with a lower success rate, compared with cystotomy, this difference was not significant. Differences in urolith removal rate between cystotomy group dogs and lithotripsy group dogs may be related to differences in postprocedural evaluation. Following lithotripsy, urolith removal was assessed in all 66 dogs with survey.
radiography and double-contrast cystography. For cystotomy group dogs, postoperative survey radiography was performed in all 66 dogs; however, double-contrast cystography was only performed in 4 of 66 dogs. Because contrast cystography is more sensitive than survey radiography for detecting small uroliths, the number of dogs with incomplete urolith removal may have been underestimated in cystotomy group dogs. Ideally, every dog would have undergone contrast cystourethrography after surgery. However, this was not possible because affected dogs in this study were recruited retrospectively. If incomplete removal was underestimated in cystotomy group dogs, this would have likely resulted from uroliths that were <3 mm in diameter. Thus, both methods appeared to be equally effective in the removal of clinically relevant (ie, those ≥3 mm in diameter) uroliths.

Further evaluation of what constitutes a treatment failure in dogs undergoing urolith removal by either modality is needed. Although any size urolith retained in the urinary tract can act as a nidus for future growth, only uroliths larger than the urethral lumen are a potential source for urethral obstruction. The definition of a treatment success is controversial. On the basis of our clinical experience, it was assumed for this study that uroliths <3 mm in diameter are able to pass through the urethra of most dogs weighing >5 kg (11 lb). In addition, because urocystoliths and urethroliths are uncommon in humans and the size of the typical canine urethra more closely resembles that of the human ureter, our definition of success was also based on those reported in the human literature for treatment of renoliths and ureteroliths. In multiple studies, fragments <3 mm in diameter were considered not clinically relevant, and treatment was considered successful if residual fragments were <3 to 4 mm in diameter. Similarly, 2 reports in the veterinary literature defined successful lithotripsy of uroliths in the canine kidney and urethra as a reduction to fragments <3 to 3.5 mm in diameter.

Even though small uroliths can pass through the canine urethra, it is unknown if uroliths <3 mm in diameter will be voided spontaneously. Thus, longer follow-up evaluation of both groups would have been ideal for this study. However, what constitutes appropriate follow-up is unknown in dogs following lithotripsy and is controversial in humans. In humans undergoing laser lithotripsy, urolith fragments are routinely left on the basis of the assumption that they will be spontaneously voided. However, postoperative evaluation of people via computed tomography revealed that only 54% of patients were completely urolith free, 84% had fragments <2 mm in diameter, and 95% had fragments <4 mm in diameter. In a retrospective study, 25 of 241 (10%) patients treated with ureteroscopic lithotripsy had postoperative obstruction caused by a residual urolith. Therefore, in humans, postoperative imaging of the urinary tract has been recommended within 3 months following treatment of ureteroliths and renoliths. Correlation of findings from these studies to dogs is challenging because uroliths in most human studies are located in the ureter and kidney. Also, in some human studies, the need for routine postoperative imaging has been questioned, and in other studies, treatment success has been defined on the basis of immediate postoperative imaging alone.

As with lithotripsy in dogs, there are also no current standard protocols for postoperative imaging for dogs undergoing cystotomy for urolith removal other than obtaining immediate postoperative abdominal radiographs. Also, to our knowledge, there are no studies that have evaluated the long-term success of cystotomy for complete urolith removal in dogs. In our study, routine postoperative (ie, at 1 to 3 months) imaging was not consistently available for both dog groups. Whether uroliths or urethrolith fragments need to be completely removed following lithotripsy or cystotomy in dogs and whether certain sized fragments can be left behind in male versus female dogs requires further evaluation.

Because there was no difference in urolith removal rate between cystotomy group dogs and lithotripsy group dogs, it was not surprising that the number of ancillary procedures to complete urolith removal was also similar. The study design and low frequency of ancillary procedures precluded the ability to determine whether there were any significant correlations between the need for ancillary procedure and patient sex, patient size, urolith number, or urolith size. However, ancillary procedures to complete urolith removal were performed more frequently in small (body weights <11 kg for lithotripsy group dogs and <9 kg for cystotomy group dogs) male dogs with multiple urycystoliths. Six of 7 lithotripsy group dogs requiring an ancillary procedure were males. Similarly, 7 of 9 cystotomy group dogs requiring an ancillary procedure were males. Unique to cystotomy group dogs were ancillary procedures directly related to the inability to remove uroliths from the urethra. Lithotripsy is an effective and safe method of removing urethroliths in dogs and humans. Thus, lithotripsy provides the clinician with a procedure associated with minimal morbidity that avoids the potential complications of urethral surgery. As laser lithotripsy becomes more available, the need for surgical management of urethroliths may diminish.

Although complete urolith removal was highly successful by either technique, laser lithotripsy required significantly more time. Compared with cystotomy, on average, laser lithotripsy required an additional 23 minutes to complete the procedure. This may not be clinically important, given that anesthesia time and procedure cost were not significantly different between cystotomy group dogs and lithotripsy group dogs. A possible explanation for longer lithotripsy times may have been lack of experience with this newer modality. Although the first 9 lithotripsy procedures were considered within the learning curve and were not included in the study, data from all of the dogs that subsequently underwent lithotripsy were included. However, it is important to recognize that surgeon experience varied in cystotomy group dogs as well; surgical urolith removal was performed by residents and faculty. Interestingly, a comparison of procedure time that included only dogs with successful outcomes (complete urolith removal) revealed no significant difference between groups. Thus, once the initial learning curve is complete, time required for either procedure may be similar.
One advantage of laser lithotripsy over cystotomy is a shorter duration of hospitalization. Lithotripsy group dogs were often discharged on the same day as the procedure. In contrast, cystotomy group dogs remained in the hospital for an additional 12 hours. The disadvantages of a longer duration of hospitalization have been reported for humans and include increased cost, increased chance of iatrogenic complications (ie, medication errors), and increased chance of infection.\(^\text{36-42}\)

Intuitively, these same disadvantages would correlate to veterinary patients; however, similar findings have not yet been reported. In addition, the lack of differences in cost and complications in this study does not support this conclusion. Because cystotomy is a more invasive method of urolith removal than lithotripsy, it is logical that longer durations of hospitalization would be recommended to closely monitor for potentially more severe complications.

There were no significant differences between cystotomy group dogs and lithotripsy group dogs in the development of major or minor complications. On the basis of these findings, laser lithotripsy appears to be as safe as cystotomy in the immediate postoperative period when removing uroliths from the lower portion of the urinary tract of dogs. A comparison of short- and long-term postoperative complications was beyond the limits of this analysis, and further studies are warranted to identify any differences among these 2 treatment modalities.

The limitations of this study are primarily related to its retrospective nature. To offset the inherent selection bias and achieve the most accurate comparisons between cystotomy group dogs and lithotripsy group dogs, this study was performed in a matched case-control fashion. Sex, urolith composition, body weight, urolith number and volume, and urolith location were used for the matching process because these variables were thought to have the greatest effect on the outcome of either procedure. To obtain the most accurate comparison between cystotomy group dogs and lithotripsy group dogs, the goal was to match each lithotripsy group dog with a cystotomy group dog of a similar urolith burden. To our knowledge, there is no current standard recommendation for the documentation and comparison of urolith burden in the veterinary literature. Evaluation of human studies\(^\text{31,33-34}\) reveals that the calculation of urolith burden is often based on the longest dimension (ie, greatest diameter) of the uroliths measured on survey radiographs or computed tomography scans. In a study\(^\text{31}\) where multiple uroliths were present, urolith burden was based on the sum of the widest dimension of each urolith present. In another study,\(^\text{41}\) preoperative computed tomography scans were used to measure the largest linear dimension of the urolith, which was then used to calculate urolith volume on the basis of the formula for volume of a sphere \((V = \frac{4}{3}\pi r^3)\), where \(r\) represents half of the greatest measured dimension of each urolith). Similarly, Wynn et al\(^\text{1}\) used the volume of a spheroid to document urolith volume when assessing the effect of the Ho:YAG laser for the treatment of canine uroliths.

After review of all radiographs, uroliths in the present study seemed to best approximate a circle. On the basis of this finding and the use of the maximal urolith dimension to document urolith size and volume in the human literature, the longest dimension (ie, greatest diameter) of the urolith was used as our measurement point and for the calculation of urolith volume. To standardize the calculation of volume and help limit interobserver variation, a single author (JMB) measured and calculated the urolith volume for each dog.

Overall, it was easy to estimate volume and compare dogs with well-defined uroliths; matches were made on the basis of urolith number and volume. The major challenge came when multiple uroliths in the bladder or urethra overlapped, which prevented calculation of total number of uroliths present and individual urolith volumes. In these instances, if any of the uroliths could be delineated and measured separately, this was done. For the remaining uroliths, urolith volume was estimated for the pool of uroliths, as uroliths of problematic sizes could not be ruled out. Thus, urolith volume was estimated by combining the pool of uroliths into single or more often multiple best fit circles by use of digital radiology software. Urolith volume for each pool was then calculated on the basis of the diameter of the circles.

To find the most appropriate cystotomy group dogs for matching, review of a larger number of dogs that underwent cystotomy over a longer period, compared with the lithotripsy group dogs, was required. Examination of records as far back as 1994 was required to find enough cystotomy group dogs that matched appropriately to the lithotripsy group dogs. It is possible that improvement in techniques such as preoperative urohydropropulsion of uroliths and the development of voiding urohydropropulsion may have affected the type of dogs that underwent cystotomy over this period. However, the cystotomy technique has likely not changed substantially over the past 10 to 12 years, so an appropriate match was considered more important for the comparison than the date of the cystotomy procedure.

Exact matching of the dogs on the basis of urolith location was limited by the retrospective nature of this study. In our study, 5 lithotripsy group dogs with multiple urethroliths were matched with cystotomy group dogs that had both urethral and urocystoliths, and 4 lithotripsy group dogs with urocystoliths were matched with 4 cystotomy group dogs with both urocystoliths and urethroliths. These affected dogs were matched because they had almost identical urolith number, size, and volume, even though urolith location was different. This discrepancy may have affected our results. However, procedure time was not different if these dogs were excluded, and in all, urolith removal was complete.

This study was also limited by the somewhat small sample size and low frequency of some of the measured outcomes (eg, ancillary procedures and complete removal). This may have masked important significant differences between cystotomy group dogs and lithotripsy group dogs for such factors. Although results of a prospective power analysis indicated that our sample size was adequate, the evaluation of a larger number of dogs may be warranted to determine the true incidence of these outcomes in either group. Although cystotomy was completed in less time, results of this study did not support our hypothesis...
that cystoneotomy was a more effective procedure. Our data indicated that there were no clinically important differences in the efficacy, required resources, or perioperative complications associated with laser lithotripsy, compared with cystotomy. Therefore, it is concluded that laser lithotripsy is a minimally invasive, safe, and effective alternative to cystoneotomy for the removal of uroliths from the urinary bladder and urethra of dogs.

b. Minnesota Uro lith Center, University of Minnesota, Saint Paul, Minn.
c. Kodak Direct View 5.2, Carestream Health, Rochester, NY.
d. Hopkins telescope, 1.9 mm × 18.5 cm, 0°, and operating sheath (used in females), Karl Storz Veterinary Endoscopy, Goleta, Calif.
e. Karl Storz Flex® Ureteroscope (used in males), Karl Storz Veterinary Endoscopy, Goleta, Calif.
g. Slimline 365 Micron Delivery System (used in females), Boston Scientific, Natick, Mass.
ta Clara, Calif.
i. N-Circle nitinol tipless stone extractor, Cook Inc, Bloomington, Ind.
j. SAS, version 9.1 for Windows, SAS Institute Inc, Cary, NC.

References


Selected abstract for JAVMA readers from the American Journal of Veterinary Research

Objective—To evaluate cardiopulmonary effects of anesthetic induction with diazepam and ketamine or xylazine and ketamine, with subsequent maintenance of anesthesia with isoflurane, in foals undergoing abdominal surgery.

Animals—17 pony foals.

Procedures—Foals underwent laparotomy at 7 to 15 days of age and laparoscopy 7 to 10 days later. Foals were randomly assigned to receive diazepam, ketamine, and isoflurane (D/K/Iso; n = 8) or xylazine, ketamine, and isoflurane (X/K/Iso; 9) for both procedures.

Results—During anesthesia for laparotomy, cardiac index and mean arterial blood pressure ranged from 110 to 180 mL/kg/min and 57 to 81 mm Hg, respectively, in the D/K/Iso group and 98 to 171 mL/kg/min and 50 to 66 mm Hg, respectively, in the X/K/Iso group. Cardiac index, heart rate, and arterial blood pressures were significantly higher in the D/K/Iso group, compared with the X/K/Iso group. During anesthesia for laparoscopy, cardiac index and mean arterial blood pressure ranged from 85 to 165 mL/kg/min and 87 to 83 mm Hg, respectively, in the D/K/Iso group, and 98 to 171 mL/kg/min and 48 to 67 mm Hg, respectively, in the X/K/Iso group. Heart rates and arterial blood pressures were significantly higher in the D/K/Iso group, compared with the X/K/Iso group. There were no significant differences between groups during either experimental period for percentage end-tidal isoflurane, arterial blood gas partial pressures, or pH values.

Conclusions and Clinical Relevance—Anesthesia of foals for abdominal surgery with D/K/Iso was associated with less hemodynamic depression than with X/K/Iso. (Am J Vet Res 2009;70:574–580)