Use of Electrohydraulic Lithotripsy in 28 Dogs with Bladder and Urethral Calculi

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**Background:** Electrohydraulic lithotripsy (EHL) has been used as an alternative to cystotomy in human medicine to remove urinary calculi. This prospective study evaluated the efficacy and safety of EHL to remove urinary calculi in dogs.

**Hypothesis:** EHL is an efficient and safe method of treatment of bladder and urethral calculi in dogs.

**Methods:** Dogs presented between January 1, 2005 and June 1, 2007 with lower urinary tract calculi diagnosed by radiographs or ultrasound examination were included in the study. Physical examination, CBC, biochemistry, urinalysis, and urine culture were performed at presentation. EHL and voiding urohydropropulsion were performed under general anesthesia. Patients received IV fluids for 12 hours after which they were rechecked by ultrasound examination and discharged with antibiotics and anti-inflammatory drugs for 5 days. All patients were reevaluated 1, 3, and 6 months after presentation by physical examination, urinalysis, and ultrasonography.

**Results:** Twenty-eight dogs (19 males, 9 females) presented with bladder or urethral calculi or both underwent lithotripsy. Their median weight was 8.3 kg. Calcium oxalate calculi were present in 22 dogs, struvite in 4, and mixed calculi in 2. Fragmentation was done in the bladder (23 dogs) and in the urethra (12 dogs). Calculus-free rate was higher for urethral than for bladder calculi in males and higher for bladder calculi in females than in males. No major complications were reported. Twelve dogs relapsed within 6 months.

**Conclusions:** Results of this study support the use of EHL as a minimally invasive treatment for bladder calculi in females and for urethral calculi in male dogs.

**Key words:** Fragmentation; Recurrence; Urethral Obstruction; Urohydropropulsion; Urolithiasis.

Lithotripsy currently is used to treat human patients with calculi in the urinary bladder, and for those with nephroliths. This technique decreases the size of the calculus and allows its passage through the urinary tract. Several types of lithotripsy have been described: laser, ultrasonic, shockwave (upper urinary tract uroliths), and electrohydraulic (EHL). Ho:Yag laser lithotripsy has become the standard urologic laser treatment used in people. Ho:Yag laser lithotripsy has been reported to be successful in treating bladder calculi in dogs,1–4 but its availability may be limited because of its high cost. EHL may be a more affordable alternative.5 The EHL electrode is passed through an endoscope and allows an electrical spark to be generated in a fluid medium (the bladder is filled with saline solution). The spark is activated for a brief period. The creation and subsequent disappearance of the spark in a fluid medium generates large pulse pressures (ie, shock waves). The electrode is placed against the surface of the urolith therefore most of the energy is absorbed by the calculus. Uroliths subjected to such high-pressure shock waves rapidly fragment owing to shearing forces that disrupt the crystal lattice.6 The uroliths can then be removed by basket and voiding urohydropropulsion. The overall success rate of EHL in humans with upper and lower urinary tract calculi is above 90%.7,8

There are 3 reports of the clinical use of EHL in the treatment of urinary tract calculi in horses. Two geldings and 1 mare were treated successfully for bladder calculi.9,10

Many experimental studies have been performed on pigs and rabbits to confirm the efficacy and safety of EHL to treat urinary calculi.11–13 One report in a dog describes the use of EHL to fragment experimentally inserted calculi in the bladder.14

EHL appears to be safe with no major complications reported in humans and animals. Minor complications also are uncommon and include minimal mucosal lesions (eg, petechiae and erosions) that do not appear to be clinically relevant.8,10,15–19

To our knowledge, evaluation of the efficacy of EHL has not been examined in dogs with spontaneously occurring bladder calculi. The purpose of this study was to evaluate the efficacy and safety of EHL in the fragmentation of bladder and urethral calculi in dogs.

**Materials and Methods**

**Criteria for Patient Selection**

Patients included in the study were presented or referred to the Centre Hospitalier Universitaire Vétérinaire (CHUV) between January 1, 2005 and June 1, 2007. Dogs that were included in the study had bladder calculi, urethral calculi, or both confirmed by ultrasonography or radiography and did not have any evidence of bladder or urethral neoplasia.

Dogs were excluded if they had calculi removed by urohydropropulsion without fragmentation or if the urethra was too narrow to allow passage of the scope. In addition, dogs were excluded from follow-up when a cystotomy was performed during the study.

A signed owner consent form was used and the study was conducted in accordance with the guidelines of the ethics committee of the University of Montreal.

All dogs underwent a physical examination, a CBC, serum biochemical profile, urinalysis, and urine culture on urine collected by
cystocentesis. Dogs were imaged by a board-certified radiologist by abdominal radiography, urinary tract ultrasonography, or both. Radiographs were taken in 25 patients to compare ultrasonography and radiography for outcomes as part of a separate study. The number of calculi, their size, the appearance of the kidneys, and bladder wall thickness all were recorded. The largest number and size of fragments on radiographs and ultrasound examination were recorded.

Dogs were entered into the study once the presence of bladder or urethral calculi was confirmed. If a urinary tract infection was present, antimicrobial administration based on culture and sensitivity results was started 5 days before performing the procedure and given for at least 3 weeks after EHL. Any animal with results that suggested the presence of urethral or bladder neoplasia was excluded from the study.

Patients were premedicated with an opioid (hydromorphone\textsuperscript{a} 0.1 mg/kg or butorphanol\textsuperscript{b} 0.1 mg/kg IM) and anesthesia was induced by IV injection of propofol\textsuperscript{c} (4 mg/kg) as needed for intubation. Dogs were maintained under anesthesia with isoflurane\textsuperscript{d} and oxygen. Patients were positioned in right lateral recumbency. The prepuce or vulva was prepared by surgical scrub and a surgical field\textsuperscript{e} was used.

**Lithotripsy**

To perform EHL, a rigid\textsuperscript{f,g} or flexible cystoscope\textsuperscript{h,i} was passed into the bladder via the urethra (Table 1). For this purpose, we used an endoscope and an electrohydraulic lithotriptor.\textsuperscript{j} Three electrohydraulic probes were available. The diameter and length were respectively 2.4 F and 700 mm,\textsuperscript{k} 2.4 F and 1,050 mm,\textsuperscript{l} and 5 F and 700 mm.\textsuperscript{m} The power setting was 2–10 U (Wolf\textsuperscript{j}) with a frequency of 8–20 Hz. Three modes of operation were available: single pulse, pulse sequence, and continuous pulses.

The bladder was emptied before the procedure and filled with warm saline via urethral catheterization.\textsuperscript{a} Once the scope was passed through the urethra and into the bladder, repeated saline flushes allowed visualization of the urethra and entire bladder. The urethra and bladder were inspected for any signs of hematoma, erosions, calculi, or irregular mucosa (Fig 1).

Calculi were identified and fragmentation was begun. The electrode was activated when in direct contact with the calculi. The lowest energy settings initially were used to fragment the calculi. Power was increased as needed to insure fragmentation. Once all calculi had undergone sufficient fragmentation to be flushed through the urethra, they were evacuated by voiding urohydropulsion. The bladder was emptied before the procedure and filled with warm saline via urethral catheterization. A stone basket\textsuperscript{o,p} was used to remove uroliths if the calculi were small enough to pass through the urethra. The fragmentation-irrigation-voiding urohydropulsion cycle was repeated until there were no visible fragments remaining in the bladder. A last passage of the cystoscope at the end of the procedure allowed us to record the appearance of the bladder mucosa. New bladder mucosal lesions were recorded. A urinary catheter was not left in place after the procedure. An anti-inflammatory drug was administered to all animals (meloxicam\textsuperscript{q}, 0.1 mg/kg SC the 1st day and then PO\textsuperscript{r} once a day for 5 days). All patients received antibiotics immediately after the procedure (cephalexin\textsuperscript{s} 22 mg/kg IV) and for 4 additional days (cephalexin\textsuperscript{s} 22 mg/kg PO q12h). If the dog was already receiving antibiotics before the study, they were continued until urine culture results were received. Treatment then was modified as needed. All patients were hospitalized in the continuous care unit (CCU) for at least 12 hours after the procedure. They received IV fluid therapy (NaCl 0.9%)\textsuperscript{u} at 60 mL/kg/d. Any hematuria, pollakiuria, or stranguria was recorded. Abdominal radiography, urinary tract ultrasonography, or both were done the day after the procedure to measure and count remaining fragments. Inclusion order, breed, and weight and patient age, size, number, type and site of calculi, urine specific gravity and pH, scope used, length of procedure, number of discharges, necessity for cystotomy, and type and time of clinical signs after lithotripsy all were recorded.

**Follow-Up**

Owners noted lower urinary tract signs (eg, pollakiuria, stranguria, and hematuria) at home and completed a form (once a day for

### Table 1. Characteristics of endoscopes used in the study.

<table>
<thead>
<tr>
<th>Type of Scope</th>
<th>Sheath Length (mm)</th>
<th>Sheath Diameter (F)</th>
<th>Viewing Angle (°)</th>
<th>Working Channel Diameter (F)</th>
<th>Used in Patients with a Minimal Weight of (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ureteroscope 1\textsuperscript{a}</td>
<td>700</td>
<td>7.5</td>
<td>60</td>
<td>3.6</td>
<td>Female: 3.3</td>
</tr>
<tr>
<td>Ureteroscope 2\textsuperscript{b}</td>
<td>675</td>
<td>7.2</td>
<td>88</td>
<td>3.6</td>
<td>Male: 6.3</td>
</tr>
<tr>
<td>Rigid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small cystoscope\textsuperscript{c}</td>
<td>215</td>
<td>14</td>
<td>25</td>
<td>5</td>
<td>4.8</td>
</tr>
<tr>
<td>Large cystoscope\textsuperscript{d}</td>
<td>215</td>
<td>17</td>
<td>25</td>
<td>7</td>
<td>11.3</td>
</tr>
</tbody>
</table>

Rigid cystoscopes were used only in female dogs. Flexible endoscopes were used in male dogs and in 1 female dog.

\textsuperscript{a}Flexible fibroscope 7330.072, Richard Wolf GmbH.

\textsuperscript{b}Flexible ureteroscope 11278 AU1/11278 A1, Karl Storz Endoscopy Canada Ltd.

\textsuperscript{c}Compact Cysto-Urethroscope 8642.403, Richard Wolf GmbH.

\textsuperscript{d}Compact Cysto-Urethroscope 8645.403, Richard Wolf GmbH.

Fig 1. Bladder endoscopy in a dog with calcium oxalate stones. The lithotripsy probe (A) is being advanced until it contacts the stone (B) while maintaining a safe distance between the probe and the mucosa (C).
the 1st week, once a week for 1 month and once a month for 5 months). All owners were instructed to add water to their dogs’ food to help prevent calculus recurrence or growth of remaining fragments. Rechecks were scheduled 1, 3, and 6 months after the procedure at the CHUV. A physical examination, urinalysis, urine culture as needed as well as urinary tract ultrasonography or abdominal radiography or both were done at this time. Owners were contacted by phone at the end of the study to evaluate client satisfaction with the procedure.

Clinical signs, urine specific gravity and pH, size, number and location of calculi, were recorded at each recheck. Relapse was used to designate growing fragments remaining in the bladder on ultrasonography examination. Calculus-free rate was defined as an absence of urethral or bladder fragments on ultrasonography and for urethral calculi, if available, on radiography. Calculus-free interval was defined as the time during which no fragments were present in the urethra or bladder. Recurrence was defined as reappearance of bladder calculi on ultrasonography. We chose the greatest number and size of calculi between both imaging methods to define relapse or recurrence.

Statistical Analysis

The size and number of calculi, breed, weight and patient age, scope used, type of stone, length of procedure, number of procedures, and clinical signs were evaluated by descriptive statistics. A Spearman test was used to evaluate the relationship between inclusion order and the median procedure time. A Wilcoxon signed rank test was used to determine whether a significant difference existed between median time of procedure and sex, type of calculus, and inclusion order, size, and number of calculi. A χ² test was used to compare clinical signs, presence, and size of fragmentation (urethra and bladder), to compare calculus-free status at T0 in the urethra and in the bladder, and to compare calculus-free rate at T0 in females and in males respectively for small calculi (< 1 cm) versus large calculi (> 1 cm), for multiple (≥ 5) versus few calculi (< 5). Significance for all analysis was defined as P < .05. Only the 1st lithotripsy for each case was used for statistical analysis.

Results

Thirty-three dogs were presented for lower urinary tract signs compatible with bladder calculi. Two females were excluded because the urethra was too narrow to allow passage of the scope. Three dogs were excluded because calculi were removed by voiding urohydropropulsion without the need for lithotripsy.

Twenty-eight dogs were included in the study and 32 procedures were performed. The study included 9 spayed females, 18 neutered males, and 1 intact male. Body weights ranged from 3.3 to 33.5 kg. The smallest female was 3.3 kg and the smallest male was 6.2 kg. The most common breeds were Schnauzers (9/28 = 32%) and Shih Tzus (5/28 = 18%). Other breeds represented by 2 or fewer dogs were Kerry Blue Terrier, Springer Spaniel, Lhasa apso, Boxer, Yorkshire Terrier, Boston Terrier, American Cocker Spaniel, West Highland White Terrier, and Jack Russell Terrier. There were 4 mixed breed dogs. Median age at presentation was 6 years (range, 3–11 years). Six of 28 (21%) dogs had previously undergone cystotomy within the past 2 weeks to 2 years. One dog had a history of congenital coagulation factor deficiency (factor XI). This dog did not develop any bleeding during lithotripsy; however, it received 1 U of plasma IV and 1 SC injection of desmopressin (2 μg/kg) before the procedure. Another dog had a history of chronic pancreatitis with an acute episode 3 months before inclusion in the study.

At presentation 24/28 (86%) dogs presented with clinical signs compatible with lower urinary tract disease; the others were asymptomatic. Biochemistry and CBC were unremarkable. Urinary tract infection was present in 3 dogs. These patients received 5 days of antibiotics before the procedure. Size of calculi ranged from 3 to 25 mm with a mean of 8.9 mm. Mean number of calculi in the bladder was 1.6 on ultrasound and 6.7 on radiographs. Seven of 28 patients (25%) had calculi ≥ 1 cm. Four patients had > 5 calculi. It was not possible to count urethral calculi because they often occurred in aggregates. Stone fragmentation was done in the bladder in 23 dogs and in the urethra in 12.

The flexible ureteroscope was used in 23 dogs, the 14 F rigid cystoscope in 6 dogs, and the 17 F rigid cystoscope in 3 dogs. The flexible ureteroscope was used in 22 male dogs and 1 female dog weighing 3.3 kg. The 14 F rigid cystoscope was used in 6 females weighing between 4.8 and 9.3 kg. The 17 F rigid cystoscope was used in 3 females weighing 11.3, 15.7, and 33.0 kg, respectively. Mean length of the procedure was 84 minutes, with a median of 80 minutes and a range of 25–195 minutes. The mean procedure duration for females was 83 minutes (range, 25–195) and for males 87 minutes (range, 35–150). The Wilcoxon test failed to detect any difference between the 2 groups (P = .6). Length of the procedure was not significantly different for calculus type (P = .62). A Spearman test identified a statistically significant negative linear relationship between length of the procedure and inclusion order (SD = −0.42, .05 > P > .02). A learning curve affecting procedure length was found.

Mean procedure length was not significantly different when comparing the urethra and bladder (P = .96), as well as for large compared with small calculi (P = .98), and for multiple versus few calculi (P = .6).

A stone basket was used in 12 dogs: in 8 males to remove urethral fragments and calculi and in 4 females to remove bladder calculi and fragments.

The number of discharges was recorded for 24/32 (75%) procedures. The mean number of discharges was 91 and the median number of discharges was 19 with a range of 1–1,559. Low power settings were used for all calculus fragmentations: power settings of < 5 U (Wolf®) and frequencies of < 14 Hz, except for 1 case (calculus of 25 mm) that required higher power settings (power of 10 U and frequency of 20 Hz). A single discharge at each time was delivered.

Macroscopic inspection of the urinary tract postlithotripsy commonly revealed erosions and petechia of the bladder mucosa but the urethral mucosa appeared much less affected. Despite multiple passages of the scope, the urethral mucosa showed minimal changes.

Calculus analysis revealed: 22/28 (79%) dogs had calcium oxalate, 4/28 (14%) had struvite, and 2/28 (7%) had mixed calculi. Mixed calculi were composed of silicate and calcium oxalate and were present in 2/28 dogs.
(7%), both males. Two dogs required cystotomy immediately after lithotripsy.

The calculus-free rate in the bladder was 5/26 (19%) and was higher in females (4/8 = 50%) than in males (1/18 = 6%) (Table 3). The calculus-free status was significantly higher when calculi were fragmented in the urethra than in the bladder (P < .0001).

The calculus-free rate was not significantly different for multiple versus few calculi (P = 1) nor for small versus large calculi (P = 1), for multiple versus few calculi in females (P = .38) and in males (P = 1); in females for small versus large calculus (P = 1), and in males for small versus large calculus (P = 1). In males, the bladder calculus-free rate was <30% throughout the study. All calculi were removed from the urethra in 12/12 dogs but calculus fragments remained in the bladder in 8 of these 12 dogs. In 4 of these latter dogs, lithotripsy was not performed in the bladder given the high risk of obstruction (large number of large bladder calculi in small male dogs). Four dogs were referred for calculi causing urethral obstruction. Lithotripsy was successful in removing multiple urethral calculi blocking the urethra thus avoiding urethrotomy.

Immediately after the procedure, 6/26 (23%) patients had no clinical signs, 4/26 (15%) had improved, and 10/26 (39%) were stable. Only 6/26 (23%) had worsened clinical signs after lithotripsy lasting <6 days with a range of 2–6 days. There was no effect of number of discharges on the prevalence of clinical signs (P = .99). There was no relationship between hematuria, pollakiuria, stranguria, and the site of lithotripsy (bladder or urethra) (P = .99).

Six-month rechecks were available in 14 dogs. One-year rechecks were available in 16 dogs (Table 2). After lithotripsy, 20 owners (20/28 = 71%) did not follow the recommendation to feed a canned urinary diet and increase water consumption.

Eighteen of 21 (86%) dogs had no clinical signs 1 month after lithotripsy. Two dogs had worsened clinical signs and growing fragments were seen on ultrasonography. These 2 dogs underwent cystotomy and lithotripsy, respectively. Uterine rupture occurred in 1 dog after accidental uterine catheterization. Another dog with chronic urethral calculi presented with a urethral tear diagnosed 2 days after the procedure.

Calculus-free interval varied between 1 month and several years and was difficult to determine for several dogs because they were lost to follow-up. One dog had no calculi for 1 month, 3 dogs had no calculi for 3 months and 2 dogs had no calculi for 6 months. One dog had no recurrence for 6 months and was lost to follow-up. Another dog was presented for a recurrence 2 years after lithotripsy. One female evacuated fragments during the period between T1 and T6. Another female spontaneously voided fragments between T1 and T3 and was lost to follow-up at T6. A third dog evacuated fragments between T0 and T3 and then was lost to follow-up.

Twelve dogs had recurrences; 9 males and 3 females (Table 3). The majority of relapses (7/12) occurred 1 month after lithotripsy. Among them, only 4 had clinical signs at the time of relapse.

By the 6-month follow-up, 6 patients had a recurrence (Table 3). Only 1 dog had clinical signs associated with lower urinary tract disease. Two females had calculus recurrence 6 and 10 months after lithotripsy. All dogs with recurrences had calcium oxalate calculi at presentation.

Three of 28 (11%) dogs needed cystotomy <1 month after lithotripsy because of persistent clinical signs and perceived risk of obstruction (Table 2). Three dogs underwent ≥2 lithotripsies (1–10 months after the first 1).

### Table 3. Stone outcome for patients during the 6-month follow-up.

<table>
<thead>
<tr>
<th>Time of Recheck</th>
<th>T0</th>
<th>T1</th>
<th>T3</th>
<th>T6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stone-free rate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5/26 (19%)</td>
<td>4/18 (22%)</td>
<td>7/16 (44%)</td>
<td>3/13 (23%)</td>
</tr>
<tr>
<td>Females</td>
<td>4/8 (50%)</td>
<td>2/6 (33%)</td>
<td>4/5 (80%)</td>
<td>2/5 (40%)</td>
</tr>
<tr>
<td>Males</td>
<td>1/18 (5.5%)</td>
<td>2/12 (17%)</td>
<td>3/11 (27%)</td>
<td>1/8 (12.5%)</td>
</tr>
<tr>
<td><strong>Recurrence rate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>—</td>
<td>1/18 (5.5%)</td>
<td>1/16 (6%)</td>
<td>4/13 (31%)</td>
</tr>
<tr>
<td>Females</td>
<td>—</td>
<td>0</td>
<td>0</td>
<td>2/5 (40%)</td>
</tr>
<tr>
<td>Males</td>
<td>—</td>
<td>1/12 (8%)</td>
<td>1/11 (9%)</td>
<td>2/8 (25%)</td>
</tr>
<tr>
<td><strong>Relapse rate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>—</td>
<td>7/18 (39%)</td>
<td>2/16 (12.5%)</td>
<td>3/13 (23%)</td>
</tr>
<tr>
<td>Females</td>
<td>—</td>
<td>2/6 (33%)</td>
<td>0</td>
<td>1/5 (20%)</td>
</tr>
<tr>
<td>Males</td>
<td>—</td>
<td>5/12 (42%)</td>
<td>2/11 (18%)</td>
<td>2/8 (25%)</td>
</tr>
</tbody>
</table>

Percentage of patients without calculi and/or fragments (calculus-free rate), growing fragments (relapse), or recurrence of calculi within the 6-month follow-up. Time of each recheck: T0, the day after the procedure; T1, 1 month after the procedure; T3, 3 months after the procedure; T6, 6 months after the procedure.

Discussion

The median age and weight of patients with urinary calculi was in agreement with previous studies.20 Twenty-
two out of 28 (79%) dogs had calcium oxalate calculi which is higher than the prevalence of 35% reported previously. This finding may be explained by the referral caseload of our hospital and the recurrent nature of these calculi.

Despite the submission of calculus fragments for analysis, mixed calculi were easily identified and therefore the nidus and outer shells were not missed.

Fragmentation was easier in the urethra than in the bladder. In the urethra, the calculi bounced less and were fragmented rapidly; visibility also was better and fragments were easily evacuated. Surprisingly, the mean procedure time was not significantly different based on the site of fragmentation (urethra or bladder). This lack of difference could be attributed to the small number of patients with urethral calculi. The urethral mucosa appeared to bleed less in comparison to the bladder mucosa. Toward the end of the study, when possible, we attempted to bring calculi into the urethra for fragmentation. Dogs undergoing urethral fragmentation did not have worse clinical signs after lithotripsy.

In the bladder, successive fragmentation resulted in mucosal trauma and some bleeding. Despite working under continuous flush, visualization became markedly reduced and it was at times difficult to identify large remaining fragments. In order to minimize mucosal bleeding, we could have used cold saline flush and a diluted solution of 10% phenylephrine. This procedure was not used because bleeding was minimal in our patients.

In previous studies, lithotripsy failures were related to the inability to fragment certain calculus types. The more lamellated and hard a calculus, the more difficult it is to break. Calculi with smooth rounded surfaces were difficult to fragment because it was harder to keep the probe in contact with the surface of the calculus. Cases in which fragment analysis identifies struvite calculi are good candidates for medical dissolution of remaining bladder fragments. In horses, calcium phosphate calculi are difficult to fragment.

Uric acid calculi also have been reported to be difficult to fragment in humans. None of the dogs in our study had uric acid, cystine, or calcium phosphate calculi.

In our study, the calculus-free rate for all patients evaluated was <50% over 6 months (Table 3). In females, the calculus-free rate was 50% immediately after the procedure and in males it was <30% for 6 months. In our study, it was easier to remove fragments in females than in males. The shorter and larger urethra of females facilitates fragment removal. Larger uroliths can be successfully voided from female dogs as compared with male dogs of similar size. We used vertical positioning during urohydropulsion to facilitate fragment expulsion as has been recommended previously.

The mean procedure duration for females was 83 minutes (range, 25–195) and for males 87 minutes (range, 35–150). The Wilcoxon test failed to show any difference between the 2 groups \( (P = .6) \). The lack of statistical difference between males and females may be owing to lack of power in the study.

In our study, urethral calculus-free rate was 100% (12/12). Urethral fragments were easily removed in males by urethral irrigation under pressure while applying pressure to the prostatic urethra by rectal palpation. A basket aided in the removal of remaining urethral fragments in 12 dogs. However, some patients were not rechecked by radiography, a more reliable imaging method to evaluate urethral calculi (Table 2).

Based on our subjective and objective observations, some limiting factors of lithotripsy were identified. First, the weight of the patient (and subsequently the size of the urethra) can be a limiting factor. Females weighing <3 kg and males weighing <6 kg could not be evaluated by our scopes owing to their small urethral diameter. A smooth or very large calculus was at times difficult to fragment and subsequently remove. Bladder calculus fragments in a male are difficult and time consuming to remove owing to the anatomy of the urethra. Bleeding of the bladder mucosa decreases visibility and subsequently the efficacy of the procedure. In our opinion, the ideal candidates for lithotripsy are females with bladder calculi or males with urethral calculi.

Some fragments may remain trapped in blood clots within the bladder after lithotripsy. It may therefore be useful to perform urohydropulsion 24 hours post-lithotripsy to aid in elimination of these retained fragments. Another way to improve fragment removal may be the use of diuretics. Furosemide was given to 2 dogs at 1 mg/kg IV twice a day. The beneficial effect of such therapy could not be determined because of small sample size.

One female dog that had a 25-mm-diameter calculus underwent cystotomy because it was impossible to remove the large number of remaining fragments from the bladder. Another approach would have been to analyze the fragments and attempt medical dissolution for struvite calculi.

Seventy-seven percent of patients were stable, improved, or had an absence of clinical signs after lithotripsy. This could be explained by the minimally invasive nature of lithotripsy, the use of an anti-inflammatory drug or both. Lesion severity has been reported to be directly related to the power setting. We used only low to middle power settings which may have minimized trauma to the urinary tract.

Twenty-three percent of patients developed more severe clinical signs after lithotripsy. We could not determine whether clinical signs observed postlithotripsy were owing to the procedure itself or to urohydropulsion because hematuria has been reported in animals undergoing only urohydropulsion. There was no relationship between hematuria, pollakiuria, stranguria, and site of calculus fragmentation (bladder or urethra).

Six patients had a recurrence of uroliths within 6 months (Table 3). Recurrence rates reported previously after cystotomy have ranged from 12 to 53% depending on calculus type. The recurrence rate after lithotripsy was in the upper range of the reported recurrence rate after cystotomy. This is in agreement with previous studies in humans that reported higher calculus recurrence rates after lithotripsy than with cystotomy. This may be explained by remaining fragments in the bladder serving as a nidus for new calculus formation. Dogs in our study also may have been predisposed to calculus
recurrence because 21% were presented for calculus recurrence after cystotomy and the majority had calculus oxalate calculi that are known to recur frequently.

Six dogs developed recurrence of calcium oxalate calculi 6 months after lithotripsy. Recurrence of calcium oxalate calculi seems to be higher after lithotripsy than after cystotomy (approximately 9% at 6 months).\(^2\)\(^6\)\(^7\) Despite written recommendations, diet and water consumption were not controlled at home. Twenty owners of 28 (71%) failed to comply with the recommendation to feed a canned diet.

In our study, 12 patients relapsed within 6 months (Table 3). This may be explained by the growth of remaining calculus fragments in the bladder. Upon closer analysis, the recurrence rate was higher in males than in females. This difference in sex may be explained by spontaneous voiding of fragments in females. The majority of the relapses occurred at T1. This very rapid growth of fragments could be explained by the fact that growth is more rapid when there is already a nidus to form a new calculus. The relapse rate might have been biased because some patients were lost to follow-up or rechecked only with ultrasonography (Table 2). We could have missed some urethral calculi or underestimated the number of calculi on ultrasonography. On the other hand, ultrasonography could lead to overestimation of relapse and recurrence rate. For example, 2 fragments could mimic a bigger calculus. The high relapse and recurrence rate may not be related only to the technique. Indeed only 29% of owners followed the recommendations to give their dog a canned urinary diet.

Results of laser lithotripsy to treat lower urinary tract urolithiasis have been reported.\(^3\) The calculus-free rate was 100% in all of the female dogs in which the holmium laser was used.\(^3\) Transurethral cystoscopy and laser lithotripsy resulted in calculus-free status in approximately 80% of the male dogs.\(^3\) In comparison to EHL in our study, laser lithotripsy appears more efficient. However, we consider EHL a cost effective alternative to treat lower urinary tract urolithiasis in dogs. The greatest challenge we encountered was not fragmentation but expulsion of urolith fragments. Perhaps our technique of fragment expulsion needs improvement. Shock wave lithotripsy also may be used to fragment bladder calculi in male dogs that are too small for transurethral cystoscopy.\(^1\)

Some limitations in our study were a small number of dogs rendering the study underpowered to detect a relationship between the type of calculus and efficacy of lithotripsy. There was no control group to compare recurrence after laser lithotripsy or cystotomy. Owners evaluated the clinical signs of their dogs at home after lithotripsy and therefore a bias by intent-to-treat may have been present.

Despite these limitations, we feel EHL is a good alternative to laser lithotripsy and surgical cystotomy. EHL was well tolerated, minimally invasive, and effectively treated urinary calculi in the majority of our patients. Based on our experience and results, we would avoid treating small male dogs with bladder calculi by EHL. This technique was especially beneficial for the treatment of bladder calculi in females and urethral calculi in males.

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Footnotes

\(^a\) Hydromorphone hydrochloride: Hydromorphone, Sandoz, Boucheville, Quebec, Canada
\(^b\) Butorphanol: Torbugesic, Wyeth, St-Laurent, QC, Canada
\(^c\) Propofol: Rapinovet, Shering-Plough Animal Health Sante’ Anmale, Pointe-Claire, QC, Canada
\(^d\) Isoflurane, AERANE, Baxter Corporation, Mississauga, ON, Canada
\(^e\) Surgical field, Opsite, Smith & Nephew Medical Limited, Hull, UK
\(^f\) Compact Cysto-Urethroscope: 8642.403, Richard Wolf GmbH, Knittlingen, Germany
\(^g\) Compact Cysto-Urethroscope: 8645.403, Richard Wolf GmbH
\(^h\) Flexible fibroscope: 7330.072 Richard Wolf GmbH
\(^i\) Flexible ureteroscope: 7.5 Fr. Flexible Ureteroscope 11278 AU/11278 A1, Karl Storz Endoscopy Canada Ltd, Mississauga, ON, Canada
\(^j\) Lithotriptor: Riwolith 2280, ICCD Endocam, Auto LP 5123, Richard Wolf GmbH
\(^k\) Urethral catheter: Urethral catheter, Kendall Sovereign trademark of Sherwood services AG, Mansfield, MA
\(^l\) Electrohydraulic lithotriptor Ultramed, 2280.121/2280.121 (Probe 2.4 F 700 mm length), Milton, ON, Canada
\(^m\) Electrohydraulic lithotriptor Ultramed, 2280.121/421 (Probe 2.4 F 1,050 mm length)
\(^n\) Electrohydraulic lithotriptor Ultramed, 2280.151 (Probe 5F 700 mm length)
\(^o\) Stones extractor 8741.03, Richard Wolf GmbH
\(^p\) Stones extractor 8741.33, Richard Wolf GmbH
\(^q\) Meloxicam: Metacam 5 mg/mL injection, Boehringer Ingelheim, Burlington, ON, Canada
\(^r\) Meloxicam PO: Metacam oral suspension 1.5 mg/mL, Boehringer Ingelheim
\(^s\) Cefazolin: Cefazolin for injection, Novopharm, Toronto, ON, Canada
\(^t\) Cephalxin per os: NOVO-LEXIN, Novopharm
\(^u\) NaCl 0.9%, 0.9% sodium chloride injection USP, Baxter Corporation
\(^v\) Acetate of desmopressine, Rhynle DDAVP intranasal solution (0.1 mg/mL), Ferring, Toronto, ON, Canada
\(^w\) Phenylephrine hydrochloride: Neo-synephrine, Hospira, Montreal, QC, Canada
\(^x\) Furosemide: Salix, Intervet, Whitby, ON, Canada

References