New Alternatives for Minimally Invasive Management of Uroliths: Nephroliths

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Abstract: Urolithiasis is a common clinical problem in small animal veterinary patients. Management of upper urinary tract calculi can be particularly challenging in small animals, as traditional surgical removal can be associated with significant morbidity. In humans, minimally invasive treatment options have replaced traditional surgical removal in many cases. This article reviews the current literature on the various types of lithotripsy and some of the newer minimally invasive options available for management of nephrolithiasis in small animal veterinary patients. An article in the January 2013 issue addressed management of lower urinary tract uroliths; a future article will discuss current management strategies for ureteroliths.

Urolithiasis is a common clinical problem in small animal veterinary patients. In the past, nephroliths were treated medically, via dissolution, or removed surgically by nephrostomy, nephrectomy, or pyelotomy. Management of calculi can be challenging in small animals because traditional surgical removal can be associated with significant morbidity1,2 and the incidence of stone recurrence in dogs and cats is high.3 Recurrence rates depend on the type of urolith, the location of the stone, the sex of the patient, and whether effective techniques have been undertaken to treat underlying causes of urolith formation. Appropriate medical therapy (e.g., dietary therapy, chelation therapy, diuresis, antimicrobial therapy), follow-up imaging, urinalysis, and urine culture are indicated to minimize the potential for recurrence of calculi. However, the recurrence rate remains high despite preventive therapy, which has led to the investigation of newer minimally invasive treatment options for veterinary patients to avoid the need for serial invasive procedures. In humans, minimally invasive treatment options have, in most cases, replaced traditional surgical removal.4

Nephrolithiasis

Many canine and feline nephroliths remain static in size and clinically silent for years. Some controversy still exists as to whether nonobstructive kidney stones worsen underlying kidney disease.5 Removal of these stones is typically recommended if the stones are increasing in size or if the patient has a partial or complete ureteropelvic junction obstruction resulting in hydronephrosis, renal parenchymal loss, worsening renal function, chronic hematuria, pain, or recurrent infections.6

In small animals, traditional intervention for treatment of nephrolithiasis involves a nephrotomy, pyelotomy, or salvage ureteronephrectomy. Complications can be severe and life-threatening after a nephrotomy and can include hemorrhage, decreased renal function, ureteral obstruction by remaining nephrolith fragments, and urinary leakage into the abdomen from the renal incision.7,8 In a study of normal cats, the glomerular filtration rate (GFR) of the ipsilateral kidney decreased 10% to 20% after a nephrotomy.9 This was clinically insignificant in normal cats, but in a clinical patient with maximally hypertrophied nephrons due to prior nephrolith-induced damage, the significance could be dramatic. Therefore, feline patients with an already compromised GFR from chronic stone disease may develop a clinically significant decline in renal function after nephrotomy.9 Also, the >30% of adult cats that develop chronic kidney disease resulting in a 67% to 75% decline of renal function10 cannot tolerate a 10% to 20%
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Further decline in GFR. Hence, nephrotomy should be avoided when possible in all cats, especially those with existing renal disease.8,9

In humans, minimally invasive procedures are typically the treatments of choice for nephrolithiasis. These procedures include extracorporeal shock-wave lithotripsy (ESWL) for nephroliths <1 to 2 cm and percutaneous nephrolithotomy (PCNL) for nephroliths >1 to 2 cm. Open surgery and laparoscopy are rarely necessary and are usually considered only after other, less invasive, options have failed or have been deemed inappropriate.4,10 Many human studies have shown ESWL and PCNL to have a minimal effect on the GFR of clinical stone-forming patients, particularly when compared with traditional surgical nephrotomy.11-13 These procedures, particularly PCNL, have been shown to be highly effective in removing all stone fragments, as endoscopic calyceal inspection is superior for visualization and fragment retrieval compared with nephrotomy.11-13

Extracorporeal Shock-Wave Lithotripsy

ESWL is a minimally invasive method used to fragment uroliths fixed in one location. It has been successfully used to fragment nephroliths and ureteroliths in dogs and ureteroliths in cats.14-16

Box 1. Candidates for Extracorporeal Shock-Wave Lithotripsy

<table>
<thead>
<tr>
<th>Nephroliths (in dogs)</th>
<th>Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydronephrosis</td>
<td></td>
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<tr>
<td>Recurrent infection</td>
<td></td>
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<tr>
<td>Pain</td>
<td></td>
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<tr>
<td>Worsening chronic renal failure</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Stone size</th>
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</thead>
<tbody>
<tr>
<td>&lt;10 mm: ESWL alone</td>
</tr>
<tr>
<td>&gt;10–25 mm: ESWL with ureteral stent or PCNL</td>
</tr>
<tr>
<td>&gt;25 mm: consider PCNL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Uretoliths</th>
<th>Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causing ureteral obstruction</td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td></td>
</tr>
<tr>
<td>Recurrent infection</td>
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<table>
<thead>
<tr>
<th>Patient characteristics</th>
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</thead>
<tbody>
<tr>
<td>Dogs with nephroliths or ureteroliths; cats with distal ureteroliths</td>
</tr>
<tr>
<td>Normal coagulation status</td>
</tr>
<tr>
<td>Not pregnant</td>
</tr>
<tr>
<td>No evidence of concurrent pancreatitis</td>
</tr>
<tr>
<td>Appropriate antibiotic therapy for &gt;48 hours before ESWL</td>
</tr>
</tbody>
</table>

ESWL = extracorporeal shock-wave lithotripsy; PCNL = percutaneous nephrolithotomy.

There are two types of ESWL unit: “wet” and “dry.” Wet units are no longer available and are only used in research settings. The newer dry units allow better imaging, better focus, and less scattering of shock waves. Because the shock waves produced are more closely focused on the stone, dry units provoke less peripheral parenchymal damage but have the potential to induce more trauma to the kidney itself. Methods to minimize renal injury in humans are under investigation and may include changes in shock-wave rate, modification of power settings, and administration of renoprotective agents like allopurinol.18-20 Renal injury does not seem to be a major concern in the few dogs treated to date, but it is currently under investigation in cats.

For ESWL, the patient is placed under general anesthesia to permit positioning and provide analgesia. Fluoroscopy is used to position the ESWL unit to target the urolith(s) (Figure 1). Nephroliths are typically fragmented with a total of 1000 to 3000 shock waves per kidney at 16 to 18 kV with a wet lithotripter (e.g., Dornier HM-3, Wessling, Germany) or a total of 900 to 3500 shock waves per kidney with a dry lithotripter (e.g., Modulith SL-20, Karl Storz Lithotripsy, Kennesaw, GA). If compromised renal function is of concern, or if bilateral ESWL is to be performed concurrently, I (A. B.) recommend treating to a maximum of 2000 to 2500 shock waves per kidney.

Patient Selection and Potential Complications

ESWL is most commonly recommended for treatment of nephroliths in dogs, rather than cats, for two reasons. First, the feline ureter does not routinely accommodate nephrolith fragment passage. Post-ESWL nephrolith fragments are typically ≥1 mm in diameter, and the typical unstented feline ureter is 0.3 to 0.4 mm in diameter. It is very important that a nonobstructive nephrolith not become an obstructive ureterolith, particularly in a feline patient. Second, there is some concern that feline kidneys are more sensitive than canine kidneys to shock waves and could experience
life-threatening bleeding.14–16 Bleeding can occur in both species, but the limited experience in cats resulted in one case having more severe hematuria than that seen in more than 150 dogs. This finding requires more investigation to confirm. Gonzales et al 11 found no significant effects on the ultrasonographic appearance of stone-free feline kidneys at 24 hours and 14 days after ESWL using a Dornier MPL5000 lithotripter. Additionally, there was no difference in GFR measured before and 14 days after treatment in these cats.21 While these results are promising, the shock-wave dosage used in healthy cats in this study may not be adequate to sufficiently fragment feline uroliths, and diseased feline kidneys likely respond differently to the effects of ESWL than healthy kidneys15 because of the hypertrophy mechanisms, which may have previously been exhausted. Feline upper-tract uroliths are typically composed of calcium oxalate monohydrate rather than calcium oxalate dihydrate, and these stones are also considered to be harder and more difficult to fragment with ESWL (BOX 2).15,22–24

ESWL is believed to be safe and well tolerated by canine kidneys.16 The severity of the renal damage is dose dependent. In dogs, it has been shown that the renal changes observed after ESWL typically result in minimal decreases in GFR and renal blood flow during the first 24 hours of treatment, and both return to baseline within 1 week.14,25,26 Intrarenal hemorrhage does occur in dogs and is typically short-lived.14,16 In one study, minor, transient changes in posttreatment creatinine levels occurred in four dogs with preexisting azotemia.27 Pre- and postprocedural diuresis is recommended in all patients.

Extrarenal complications with ESWL include abdominal pain, diarrhea, and pancreatic injury (i.e., increased amylase, lipase, liver enzyme, and trypsin-like immunoreactivity levels). Shock wave–induced “pancreatitis” occurred in approximately 2% to 3% of dogs treated by ESWL in one study, based on elevated biochemical parameters.28 In the author’s (A. B.) experience, this complication is rarely associated with clinical signs. Shock wave–induced dysrhythmias (e.g., ventricular extrasystole, atrial extrasystole, sinus bradycardia) have occurred in a few human patients (<8%); this rate has declined since the development of the dry lithotripter and the ability to deliver shock waves in a gated fashion with the cardiac rhythm.29

ESWL treatment was reported to be successful in approximately 85% of dogs with calcium-containing nephroliths and ureteroliths.14 Successful fragmentation of renal stones was achieved in 90% of dogs, but some dogs required two treatments.14 Overall, 30% of dogs required more than one ESWL treatment for adequate fragmentation of nephroliths when wet lithotripsy was used;14 when an old dry unit (Modulith SL-20) was used, up to 50% of dogs required more than one treatment.13 In my (A. B.) experience, the newer dry units are more powerful and effective, with a more focused beam, resulting in lower stone retreatment rates. Approximately 15% of cases need a second treatment, although our practice is to empirically place a concurrent ureteral stent in dogs with stones >1 cm. Success is stone and patient dependent. Stone size and composition are clearly associated with success in human urology, and the same seems to be true in veterinary medicine.

In a series of 140 dogs with nephroliths or ureteroliths treated by ESWL,30 the most common complication was ureteral obstruction by stone fragments, which occurred in approximately 10% of dogs. With the advocacy of ureteral stent placement for larger nephroliths (>1 cm) before ESWL, this risk has declined. The presence of the ureteral stent may facilitate the passage of the stones due to passive ureteral dilation and helps to improve fluoroscopic identification of small ureteral stones during the ESWL treatment, making treatment more effective.31,32

**Use of Stents**

Ureteral stents have been placed in dogs to improve stone fragment passage after lithotripsy. In my (A. B.) experience, success rates approach ~85% with one treatment when ureteral stenting is concurrently performed. Stents are typically placed to prevent subsequent ureteral obstruction and allow for passive ureteral dilation (in my experience [AB]). Stent-induced passive ureteral dilation is beneficial in cases with large nephroliths (1 cm), as the risk of developing a ureteral obstruction during passage is the major concern (FIGURE 2). Animals with ureteral stents often require shorter hospital stays, as the concern for post-ESWL ureteral obstruction is diminished. There is some evidence in research models that ureteral stenting may diminish ureteral peristalsis,33,34 which may ultimately result in slower stone passage after ESWL.35,36 For this reason, patients with stented ureters are typically given 3 months to pass stone fragments before a second treatment is considered.

**Follow-Up**

Postprocedure analgesia is typically accomplished with

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**Box 2. Urolith Composition in Order of Ease of Fragmentation (Least to Most Resistant)**

- Struvite
- Urates
- Calcium oxalate dihydrate
- Cystine
- Calcium oxalate monohydrate

In humans, struvite stones are considered harder to fragment than calcium oxalate, although this has not been my (A. B.) experience when using intracorporeal lithotripsy or extracorporeal shock-wave lithotripsy in companion animals.

Alternatives for Minimally Invasive Management of Uroliths: Ureteroliths.”

A standard medical approach is started based on urolith composition. Follow-up radiography and ultrasonography are typically recommended 1 day after treatment, then in 2 to 4 weeks, and then every month thereafter until all stones are passed.14–16 A second treatment is required in 15% to 35% of cases to achieve effective fragmentation if the remaining fragments appear too large to safely pass through the ureter.14,16 If fragments that have passed into the urinary bladder are not voided within 1 or 2 months after ESWL, voiding urohydroplulsion4 or cystoscopic stone basketing is recommended.14 If stone fragments remain in the kidney or ureter after 2 or 3 months, repeat ESWL is suggested as long as there is no concurrent ureteral obstruction. In cases of ureteral obstruction, placement of a ureteral stent is recommended.4b

We do not recommend repeat ESWL of nephroliths within 4 weeks; however, there are no veterinary references supporting our clinical practices. The optimal time to carry out a repeat treatment of the same kidney has not been adequately studied, even in humans. A wait time of 2 weeks has been discussed in human medicine to allow enough time for stone passage before re-treating. By extrapolation, as stones are expected to pass within 4 weeks after ESWL in dogs, we recommend waiting 4 weeks before re-treating the same kidney.

Percutaneous Nephrolithotomy

In humans, PCNL is typically performed for large or impacted nephroliths (>15 to 30 mm).37,38 In small animals, PCNL is considered if ESWL fails or is not available, if cystine stones (which are resistant to EWSL) are present, or if the stone is >15 mm. PCNL has been performed in a handful of canine patients to date, as well as a feline patient. Typically, a combination of ultrasonographic, endoscopic, and fluoroscopic guidance is used. Patient size is less of a factor for PCNL than for ureteroscopy; the smallest canine patient in which I (A. B.) have successfully performed PCNL weighed only 6.8 lb (3.1 kg).

Typically, for PCNL, a renal access needle is used to access the renal pelvis through the greater curvature of the kidney under ultrasonographic guidance. Subsequently, using fluoroscopic guidance, a sheath (12 to 30 Fr) and balloon dilation catheter combination is advanced over a guide wire through the renal parenchyma, into the renal pelvis, and onto the nephrolith. A mini-PCNL approach using an 18- or 24-French access kit is used for smaller patients. Once the sheath is in the renal pelvis, a nephroscope is used to identify the stone. If the stone is small enough, a stone-retrieval basket is used to remove it. If the stone is larger than the sheath, intracorporeal lithotripsy (ultrasonic, electrohydraulic, or Ho:YAG [holmium:yttrium, aluminum, garnet] laser) is used to fragment it (FIGURE 3 and VIDEO 1†). Once the stone fragments are small enough to fit through the sheath, they are removed. If more than one stone is present, the sheath and scope can remain in the renal pelvis until all stones have been fragmented and removed. A locking-loop nephrostomy tube (5 or 6 Fr) is left in place to allow the small hole to seal and form a nephropexy.46

Surgical-assisted endoscopic nephrolithotomy (SENL) is a PCNL-like procedure that is performed using a rigid endoscope during an open laparotomy, resulting in excellent magnification of the renal pelvis for stone retrieval.40,41 For this procedure, the greater curvature of the kidney is punctured with a renal access needle and pyelography is performed. A guide wire is then advanced into the renal pelvis under fluoroscopic guidance, and a balloon dilation catheter, preloaded with a matching sheath, is advanced over the wire onto the nephrolith. The balloon is dilated, and the sheath slides smoothly over the balloon. The balloon is then withdrawn, and the scope is inserted through the sheath for stone removal. The stone can be removed with a basket if it is small enough to pass through the sheath, or it can be fragmented by lithotripsy before being removed. Using a balloon–sheath combination creates a tamponade effect so that there is very little risk of hemorrhage. For SENL, a nephrostomy tube is not necessary.

For more information on voiding urohydroplulsion, see “New Alternatives for Minimally Invasive Management of Uroliths: Lower Urinary Tract Uroliths” in the January 2013 issue of Compendium: Continuing Education for Veterinarians®.

†Ureteral stent placement will be discussed in more detail in the third article in this series, “New Alternatives for Minimally Invasive Management of Uroliths: Ureteroliths.”

*To watch the video referred to in this article, please visit www.vetlearn.com.
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Box 3. Hospitals Routinely Performing Minimally Invasive Procedures to Treat Nephroliths

The Animal Medical Center
510 E. 62nd Street
New York, NY 10065
Contact: Dr. Allyson Berent
Email: Allyson.Berent@AMCNY.org
Phone: 212-838-8100
Currently performing extracorporeal shock-wave lithotripsy, percutaneous nephrolithotomy, and surgical-assisted endoscopic nephrolithotomy

Purdue University School of Veterinary Medicine
West Lafayette, IN 47906
Contact: Dr. Larry Adams
Email (Referral desk): PUSAH@purdue.edu
Currently performing extracorporeal shock-wave lithotripsy

because the hole can be closed by direct suturing of the renal capsule. Because a balloon is used to dilate the renal parenchyma, minimal nephron loss occurs and the tissue does not need to be incised. SENL is now being performed routinely on canine kidneys in my practice (A. B.).

Other surgical-assisted approaches place the scope through a blunt puncture in the greater curvature (lateral margin) of the kidney until it penetrates the pelvis. Calculi can be removed by using a stone retrieval basket placed through the operating channel of the cystoscope.

Unlike nephrolithotomy, PCNL and SENL do not require transient occlusion of renal vessels, and they result in a much smaller hole in the renal parenchyma than a nephroscopy. Placing sutures in the capsule andapposing the small incision can close the renal access point. The use of the endoscope also allows differentiation between intraluminal calculi and mural calcification, which can also be assessed before surgery with the use of computed tomography—intravenous pyelography. Care must be taken to assess all areas of the renal pelvis and renal calices, as small calculi can remain if fluoroscopy and contrast nephrography are not used concurrently.

We recommend the use of fluoroscopy when performing PCNL and SENL to identify any remaining stone fragments in the renal calices. This is also recommended in human urology.¹⁰

Conclusion

ESWL is an efficient minimally invasive technique for the treatment of upper urinary tract calculi (nephroureterolithiasis) in dogs, provided that the candidates are well selected and the facility is prepared for the management of animals with upper urinary tract obstructions if a ureteral obstruction occurs (BOX 3). The use of concurrent ureteral stenting in veterinary medicine has made ESWL safer for small dogs with large stone burdens. PCNL is the best minimally invasive alternative to remove large stone burdens in the kidney (>1.5 to 2 cm), particularly when ESWL fails. It is important to remember that many of the procedures described above have been performed in a small number of patients in only a few facilities; therefore, they are still considered investigational.

Minimally invasive management of urolithiasis in veterinary medicine is following the trend seen in human medicine. Over the past 10 years, the veterinary community has made great strides in adapting the technology used for humans to be more applicable to small animal veterinary patients. Conditions that have traditionally been considered a major therapeutic dilemma, like ureteral obstructions, kidney stone recurrence, and urethral obstructions, now have new, effective, and safe options.

References


35. Mustafa M, Al-El-Dein B. Stenting in extracorporeal shockwave lithotripsy; may enhance the passage of the fragments! *J Pak Med Assoc* 2009;59:141-143.


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1. Removal is indicated for upper urinary tract stones that are
   a. obstructing urine flow.
   b. causing hydroureter/hydronephrosis.
   c. associated with discomfort or recurrent pyelonephritis.
   d. all of the above

2. After nephrotomy, the glomerular filtration rate in a cat
   a. increases by 10% to 20%.
   b. increases by 30% to 50%.
   c. decreases by 10% to 20%.
   d. decreases by 20% to 30%.

3. Which treatment option should be considered first for a dog with a 25-mm nephrolith obstructing the renal pelvis?
   a. nephrotomy
   b. percutaneous nephrolithotomy
   c. extracorporeal shock-wave lithotripsy
   d. ureteronephrectomy

4. Extracorporeal shock-wave lithotripsy (ESWL) treatment was reported to be successful in approximately _____ of dogs with calcium-containing nephroliths and ureteroliths.
   a. 50%
   b. 65%
   c. 70%
   d. 85%

5. With a traditional wet lithotripter, reintervention was reported to be necessary in ______ of patients with nephroliths.
   a. 5%
   b. 10%
   c. 30%
   d. 50%

6. What is the most common complication after ESWL to treat upper urinary tract stones?
   a. acute renal failure
   b. cardiac arrhythmias
   c. ureteral obstruction
   d. pancreatitis

7. All of the following are indications for treatment with ESWL in dogs except
   a. pregnancy
   b. hydronephrosis
   c. stone size <10 mm
   d. pain

8. Which statement is false with regard to percutaneous nephrolithotomy (PCNL)?
   a. PCNL requires a ureterotomy to access the renal pelvis.
   b. Once the sheath is in the renal pelvis, a nephroscope is used to identify the stone.
   c. Access to the renal pelvis is gained percutaneously through the greater curvature using fluoroscopic guidance and a renal access needle.
   d. PCNL is typically performed for large, impacted nephroliths in people.

9. Which statement regarding surgical-assisted endoscopic nephrolithotomy is false?
   a. It is performed using a rigid endoscope during an open laparotomy.
   b. It results in excellent magnification of the renal pelvis for stone removal.
   c. A nephrostomy tube is necessary in all patients.
   d. Calculi can be removed with a stone retrieval basket.

10. Which statement is false with regard to ESWL?
    a. Cats with nephroliths are not good candidates for ESWL.
    b. Diuresis is required after this procedure.
    c. ESWL requires the patient to be under general anesthesia.
    d. ESWL uses a laser to fragment uroliths.