Urolithiasis is the formation of calculi (“stones”) or concretions of mucus, protein, and minerals in the urinary tract. It is the most common cause of urinary tract disease in small ruminants. Clinical signs are variable depending on the severity of the obstruction. Uroliths can be calcium, struvite, or silicate based; however, struvite and amorphous magnesium calcium phosphate are the most common urolith types observed in small ruminants. Although urethral process (vermiform appendage) amputation is widely considered the first line of treatment, reobstruction is common within the first 36 hours. Surgical interventions such as temporary tube cystostomy, perineal urethrostomy (PU), modified proximal perineal urethrostomy, vesico-preputial anastomosis (VPA), and urinary bladder marsupialization (BM) are reported to carry an improved prognosis for long-term survival. PU carries a lower proportion of long-term success (> 12-month survival time) when compared with VPA and BM. Stoma stricture and urine scald are the most commonly observed surgical complications. Currently, the literature provides minimal direction for clinician decision-making in managing these cases while accounting for patient history, client financial ability, composition of calculi, and potential treatment complications. Small ruminant urinary obstructions are challenging and complicated conditions to treat, due to their multifactorial etiology, ruminant urogenital anatomy, and the variety of imperfect treatment options available. The purpose of this article is to provide veterinary practitioners with decision trees to guide management and treatment of urolithiasis in small ruminants.

Urolithiasis is the formation of calculi (“stones”) or concretions of mucus, protein, and minerals in the urinary tract. It is the most common cause of urinary tract disease in small ruminants. Although presentation to veterinary services is often sporadic, urolithiasis can have a significant economic and production impact on livestock, show animals, and pets worldwide. Obstruction in small ruminants typically occurs in the urethra of intact and castrated males, more specifically at the urethral process, or vermiform appendage (VA), and sigmoid flexure. This contrasts to steers and bulls, which more commonly obstruct distal to the sigmoid flexure. Many factors, such as diet, age, sex, breed, genetics, season, soil composition, water intake, hormone levels, feed and mineral composition, and urogenital infection play a role in the development of urolithiasis.

Calculi typically form in the urinary bladder and can remain undetected as many animals are asymptomatic. When calculi migrate to the urethra, they can cause a complete or partial obstruction of urinary flow. Clinical signs are variable depending on several factors, such as the degree of obstruction and number, volume, location, and mineral composition of the calculi. Presenting complaints include, but are not limited to, depression, mild bloating, abdominal distention, anorexia, colic, tail flagging, stranguria, hematuria, anuria, and vocalization.

Uroliths are most commonly composed of calcium apatite or phosphatic-based calculi (e.g., calcium hydrogen phosphate dihydrate and magnesium ammonium phosphate [struvite]). Silicate and calcium carbonate uroliths may occasionally be present. Jones et al in 2017 evaluated 49 sheep and goats that presented for obstructive urolithiasis and found that amorphous magnesium calcium phosphate (AMCP) was the majority component with struvite (39%) uroliths or as a pure component (11%) followed by calcium carbonate as the second most frequent urolith (31%). In the author’s experience, young goats (0 to 4 months old) present with AMCP and struvite stones, while calcium carbonate stones are more commonly encountered in mature goats (> 37 months old). Similar results were observed in other studies.

There are many scientific publications on the topic of small ruminant urolithiasis, which include literature reviews, descriptions of medical and surgical treatments, calculus composition, and epidemiological studies. To the author’s knowledge, there is minimal direction available for clinician decision-making in the stabilization and treatment of these animals.
This article will provide veterinary practitioners with decision trees that will ultimately help guide management and treatment of urolithiasis in small ruminants.

**Evaluation, Triage, and Care of the Small Ruminant with Urethral Obstruction for the General Practitioner**

Urolithiasis in small ruminants is a common and difficult condition to manage and often requires surgical intervention. Initially, animals may be managed successfully with urine acidifiers, dietary adjustments, and amputation of the vermiform appendage; however, surgical options should be considered when medical management fails to resolve the obstruction or if reobstruction occurs.9,10,15

Appropriate management of these cases can be difficult and is influenced by clinician comfort and level of training, owner finances and goals for the patient, health status of the animal, and integrity of the urinary tract. Therefore, decision trees are a helpful tool for practitioners to reference in simple or complicated cases to make appropriate stabilization and treatment decisions. The following approach outlines a diagnostic and treatment plan for small ruminants with urethral obstruction using the decision trees (Figures 1 and 2).

Managing obstructed small ruminants on an ambulatory basis is more challenging than in a hospital setting for several reasons, including access to laboratory and surgical facilities, availability of assistants, and methods of restraint. However, procedures can be performed in the field to stabilize a patient and/or resolve the obstruction (Figure 1).

**Initial assessment**

The first step is to understand the patient’s history, including diet and access to clean water, followed by a complete physical examination. Most of these animals present with at least mild dehydration or hypovolemia, depression, mild bloat and/or abdominal distention, tail flagging, straining, with or without stranguria and/or hematuria, anuria, and vocalization. Abnormalities in vital parameters typically include tachycardia and tachypnea and, in some cases, mild fever.

**Laboratory testing**

Ideally, initial bloodwork should consist of a packed cell volume (PCV), total protein, and a chemistry panel. Determining acid-base status and electrolyte abnormalities is especially warranted if general anesthesia will be required. Small ruminants with acute (< 24 hours) urethral obstruction, and without bladder or urethral rupture, are often mild to moderately hemoconcentrated and frequently have mild to moderate prerenal and postrenal azotemia. Patients with chronic obstruction (> 24 hours) exhibit more severe hemoconcentration, azotemia, as well as acid-base and electrolyte derangements.6 These systemic abnormalities, especially hyperkalemia, increase the

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**Figure 1**—Decision tree for treatment considering finances for referral of small ruminants with urinary obstruction.
potential for anesthetic and postoperative complications, specifically fatal cardiac arrhythmias. Therefore, adequate stabilization of the critically ill patient is necessary before surgical intervention under general anesthesia. In the hospital, this is achieved by urinary bladder decompression and appropriate IV fluid therapy. This may also be possible in the field, and, if the animal is referred, it may be important to decompress the urinary bladder by cystocentesis or placement of a Bonanno catheter (Becton-Dickinson) to prevent urinary bladder rupture during transport.

**Intravenous catheter placement**

The IV catheter should be placed when fluid therapy and/or intravenous medications are needed. The right or left jugular groove is clipped and aseptically prepared, and the catheter is placed using aseptic technique. The authors prefer the extended use Mila catheters (Extended Use MILACATH, MILA International, Inc), and the gauge will depend on the patient size (18 to 14 gauge). Local anesthesia (approx 1.5 mL of 2% lidocaine) is administered subcutaneously at the intended site of catheter placement. A small, 2- to 3-mm skin cut-down with a No. 15 scalpel blade eases placement of the catheter. A T-port extension set (B. Braun Medical Inc.) is attached to the catheter. The catheter and extension set are secured with a 2-0, nonabsorbable, monofila-

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**Figure 2**—Decision tree for surgical management of small ruminants with urinary obstruction.
status) of balanced electrolyte solution should be chosen based on chemistry and electrolyte results. Hyperkalemia can be corrected by IV administration of saline (0.9% NaCl) solution, 2.5% to 10% dextrose (0.5 mL/kg), and calcium. Administration of IV fluids to an animal with complete urethral obstruction will cause diuresis and can increase the likelihood of bladder or urethral rupture, so this should be done in conjunction with urinary bladder decompression.

**Diagnostic imaging**

Ultrasonography and radiography are important diagnostic tools to aid in determining the location of calculi and their likely composition (Supplementary Figure S1). When evaluating the obstructed small ruminant, the authors start with a transcutaneous ultrasound examination of the urinary tract. A curvilinear 7.5 MHz is the preferred transducer; however, 3.5-MHz linear transducers can be used in small and thin animals. The ultrasound settings should be adjusted depending on the machine, body condition of the animal, and practitioner’s preferences. If the animal needs sedation to allow thorough examination, morphine (0.1 mg/kg, IV) or butorphanol (0.05 mg/kg, IV) with midazolam (0.1 to 0.2 mg/kg, IV) work well. These drug combinations are usually sufficient to allow for a diagnostic workup (IV catheter placement, ultrasound examination, radiographs, cystocentesis with or without bladder catheterization, and urethral process amputation) on an obstructed animal with the addition of local anesthesia (lidocaine, 2%) for painful procedures.15 If additional sedation is needed, a redose of 50% to 100% of the initial dose, or the addition of acepromazine (0.05 mg/kg, IV or IM), allows adequate muscle relaxation to place the animal on its rump (easier to extrude the penis) or in lateral recumbency to finish the examination. Ultrasound of the kidneys, urethra, urinary bladder, and the ventral abdomen is evaluated in longitudinal and cross-sectional planes, starting at the xyphoid, moving caudally, and ending in the inguinal region to determine if free fluid is present in the abdomen.16 The presence of free fluid can be indicative of a uroabdomen secondary to bladder rupture or tearing. In cases where the urinary bladder is injured (hemorrhagic, congested, or necrotic), a small volume of free fluid may be noted in the caudal abdomen. The kidneys can be examined in longitudinal and cross-sectional planes.17 The last two intercostal spaces and the region immediately caudal to the last rib are scanned on the right side to evaluate the right kidney.17 The left kidney can be identified caudal to the right kidney in the right, dorsal paralumbar fossa.17 The presence of severe hydronephrosis with a loss of visible cortical tissue in both kidneys warrants a poor prognosis for restoration of normal renal function.17 The bladder is more consistently evaluated in the right and left inguinal regions with the animal in a recumbent position (can be done in a standing position on cooperative animals).17 The urinary bladder may be large and distended in the acutely obstructed animal but can become thickened and devitalized with chronicity. Echogenic material may be visible, especially in the bladder apex. The ureters are not easily and reliably identifiable in a routine examination unless markedly distended. The urethra is easily examined transcutaneously with a 3.5-MHz linear ultrasound transducer in the short axis (cross section) starting at the level of the tuber ischii and moving distally until the complete length of the urethra is examined.17 The sigmoid flexure is best visualized by extending the hind limbs cranially. Calculi or sediment can be easily noted within the urethral lumen when acoustic shadowing is observed.17 Radiography can be a valuable diagnostic tool in the evaluation of these cases, especially when calculi are radiopaque, thereby helping guide therapeutic decisions.1 A recent study found that 91.6% of cases with calcium carbonate uroliths had visible calculi on radiographs. However, no AMCP/struvite, struvite, or AMCP uroliths were visible on radiographs.8,18,19 Resolution of calcium-based stones may be difficult without surgical intervention; however, radiolucent stones may resolve with acidification of the urine, although reoccurrence is still an issue.8,10 Radiographs should be performed with the animal in lateral recumbency. Prior to taking radiographs, the practitioner should try to clean and remove as much dirt or material that could potentially create artifact or confound the diagnostic results. Two or three views can be taken depending on the animal’s size. A lateral view with the hind limbs in a neutral position and a lateral view with the hind limbs extended cranially should be obtained. Care should be taken to ensure that the abdomen (including the urinary bladder), pelvis, perineal region, and distal urethra (up to the external preputial orifice) are present on the combined views.

**Cystocentesis or temporary percutaneous urinary bladder catheterization**

Cystocentesis (ultrasound guided is preferred) is indicated to improve patient comfort and temporarily reduce bladder distention to limit the risk of necrosis or rupture of the bladder if a more sustained method of bladder decompression is not feasible (Figure 3). Common disadvantages can include, but are not limited to, uroperitoneum induced by persistent urine leakage from the bladder at the cystocentesis site and propagation of bladder wall tearing from the site of cystocentesis.6 The authors’ preferred method of bladder decompression is the ultrasound-guided insertion of a temporary, percutaneous urinary bladder catheter (Bonanno Catheter Suprapubic, [introducer needle, 14-gauge X 11-inch catheter with a 18-gauge X 11-inch needle]; Becton-Dickinson) (Figure 4). This catheter can provide sustained bladder decompression for up to approximately 48 hours, if well maintained, and facilitates diuresis.20 Failure or complication associated with the percutaneous urinary bladder catheters is common and may include displacement from the bladder, kinking of the catheter, or obstruction of the catheter lumen.20 Care should be taken not to perforate any viscera with the catheter, especially in bloated animals. The Bonanno
catheter (Becton-Dickinson) should only be left in place for 12 to 48 hours until surgical intervention can be performed and the patient has been stabilized with IV fluids. Leaving the catheter in for extended periods of time (> 48 hours) can lead to kinking, clotting, displacement, or tearing. This type of catheter is excellent for systemic stabilization prior to surgery but is not intended for sole treatment. Placement of the percutaneous urinary bladder catheter is most easily accomplished with the patient in "lazy" dorsal recumbency, where the head and trunk are laterally recumbent and the pelvis is dorsally recumbent.

With the use of the curvilinear 7.5-MHz transducer in a longitudinal (long axis) orientation, the distended bladder is localized in the inguinal area. The caudal abdomen is clipped and aseptically prepared. The skin is locally anesthetized with 1 to 2 mg/kg of 2% lidocaine (MWI/VetOne) administered subcutaneously. A 2- to 4-mm stab incision with a No. 15 scalpel blade is made in the skin to ease catheter placement. The ultrasound transducer is covered steriley (Ultrasound Probe Cover 6 X 48 Inch Polyethylene Sterile) and positioned longitudinally in a cranial to caudal direction. Alcohol or sterile gel is applied to improve visualization of the bladder. The transducer is held with the nondominant hand, and the catheter is held with the dominant hand. It is often necessary to grasp the catheter mid shaft with a sterile glove for sufficient control over its direction. The catheter is ultrasound guided into the mid body of the urinary bladder. Once accurate positioning of the catheter is confirmed both visually and by the free release of urine from the catheter, the stylette is held in place and the catheter is advanced into the bladder (Figure 5). The stylette is subsequently removed. A urine sample can be acquired aseptically at this time for urine analysis and/or culture. The catheter is secured using a 2-0 nonabsorbable, monofilament suture on a straight needle.

Considerations for Surgical Management of the Small Ruminant with Urethral Obstruction

Regional anesthesia

 Epidural space injection is a helpful and relatively easy procedure that provides analgesia and regional anesthesia. The injection can be performed at the sacrococcygeal or intercoccygeal space (caudal epidural) or at the lumbosacral space (cranial epidural). If sufficient volume is injected in the caudal epidural space, it will diffuse rostrally. The caudal epidural injection provides analgesia to structures present in
the pelvis and surrounding tissues. The anesthetic drugs are injected into the sacrococcygeal (S4–Co1) or first intercoccygeal (Co1–Co2) spaces. The authors prefer to use a 0.2 mL/kg total volume dose for the epidural injection. We recommend the use of preservative free morphine (0.1 mg/kg) and 0.25 of total volume of 0.5% Bupivacaine, finishing the total volume dose with saline solution (quantum sufficit to 0.2 mL/kg). A 1.5-inch (3.8-cm), 20- or 18-gauge needle is passed on midline, between the vertebrae at a 0° to 15° angle to perpendicular. The needle is inserted to a depth of 1 to 2 cm, depending on the animal’s size, and the hub of the needle is filled with saline solution or the local anesthetic. The needle is advanced until the fluid is aspirated as it enters the epidural space, due to the subatmospheric epidural saline solution or the local anesthetic. If the needle is correctly placed, there is minimal resistance to injection. Another technique is to use a Tuohy epidural needle (3.5 inch [8.9 cm], 20 or 18 gauge [B. Braun Medical Inc.] with a loss of resistance syringe. If the needle is correctly placed, there is minimal resistance and injection should be effortless.

**Penile extrusion and VA amputation**

With the animal sedated, extrusion of the penis is easier with the animal positioned on its rump. Lidocaine cream or a splash block should be applied to the prepuce. A hand-over-hand technique is used to bring the glans penis outside the preputial opening. Allis tissue forceps can then be applied to the glans penis to keep the penis exteriorized, taking care not to damage the glans or the urethra (place forceps on shaft or preputial mucosa). Once identified, the VA is visualized and sharply excise with scissors or a blade. If obstruction is in the VA, urine should start flowing. If no urine is observed, additional stones are likely present more proximal in the urinary tract.

**Surgical correction**

There are a number of surgical procedures available for treatment of simple or complicated urinary obstructions such as urethrostomy,6,23-25 bladder marsupialization,6,15-17 tube cystostomy (TC), penile catheterization,6,23 and penile amputation,6,25,26 though each has its limitations. However, tube cystostomy together with medical dissolution of calculi is an effective technique for resolution of obstructive urolithiasis in small ruminants.6,27 For the authors, TC with or without urethrotomy with bladder lavage and urethral flush are the preferred methods of treatment.6,15

**Postoperative care**

Most patients receive IV fluids for 24 to 48 hours depending on how systemically stable they are. Systemic antibiotics (procaine penicillin, 22,000 IU/kg, IM, q 12 h) and ceftiofur sodium, 2.2 mg/kg, SQ, q 24 h) are administered until the tube is removed (10 to 14 days). Systemic anti-inflammatory drugs (flunixin meglumine, 1.1 mg/kg, IV, q 24 h) and urine-acidifying products (ammonium chloride, 250 to 325 mg/kg, PO, q 12 h) are also part of the postoperative care. The animals should be kept with an Elizabethan collar to avoid biting on the Foley catheter and monitored closely for straining and urine dripping from the tube. Typically, the obstructed animals will remain with the Foley catheter (Rusch Gold 2-way Foley catheter sizes, 12 to 24 outer diameter, Teleflex Medical Sdn Bhd) open for 10 to 14 days postoperative. On day 10, the catheter is clamped for 1 to 2 hours at a time, and the patient’s comfort and tube patency are evaluated. If the patient remains comfortable, it is left clamped until the animal urinates or becomes uncomfortable (straining, anuria, tail flagging, belly kicking, or vocalization). If urination is observed and the patient is comfortable, the tube is left clamped for 24 hours and then removed. However, if the patient urinates but becomes uncomfortable, the tube is unclamped, and the patient is given a 4- to 6-hour break before it is clamped again. If the patient is uncomfortable and no urine is observed from the penis, the patient is given an additional 1 to 2 days before the process of clamping is repeated. If the patient is unable to urinate after the additional 1 to 2 days, a contrast urethrogram with radiographs or a computed tomography is performed to evaluate urethral patency and evidence of possible stricture/obstruction. Based on the imaging findings, additional surgical treatment may be warranted. If urethrotomy was performed with surgical closure, the site should be monitored carefully when the Foley catheter is clamped to be sure there is no extravasation of urine into adjacent tissues. Alternatively, the urethrotomy site can be left open to heal by second intention, making it less of a concern when the Foley is clamped.

**Discussion**

To the authors’ knowledge, this is the first article in which decision trees were constructed to provide appropriate management and treatment options for critical cases of urinary obstruction in small ruminants (Figures 1 and 2).

Providing practitioners with relevant information regarding prognosis and success rates of different surgical procedures can help a clinician make informed decisions based on previous experiences. Several factors can influence the overall prognosis in the small ruminant with urinary obstruction.7 Poor clinical condition upon presentation, obesity, castration, evidence of uroperitoneum, abnormal PCV, severely increased serum creatinine concentrations, and increased activity of creatine kinase have been associated with an increased risk of nonsurvival in a recent publication.28 Other factors have been linked to survival after surgical TC for treatment of obstructive urolithiasis in small ruminants. Sheep carried a poorer prognosis when compared with goats after tube cystostomy.27 Serum potassium of 5.2 mg/dL, no fluid in the abdomen, and no urethral process amputation before admission were associated with improved survival rates.27 These factors should be considered in the selection of small ruminant cases of urolithiasis for treatment and in management after surgery.27
VA amputation is a common initial treatment performed by practitioners and owners to reestablish urine outflow and bladder emptying. It has been reported to be successful in 50% to 60% of small ruminants; however, the likelihood of reobstruction is high (> 80%) within the first 36 hours. The proportion of animals with a successful long-term (2 to 24 months) outcome from TC is reported to be 76% to 80%. When TC and urethrotomy are combined, 75% of goats did not show recurrence of signs of urinary obstruction, and 87.5% of goats survived long term (> 12 months). However, long-term complications such as recurrent urethral obstruction or surgical complications led to euthanasia in 16% to 28% of cases in 2 different studies.

More drastic surgical procedures carry a lower proportion of long-term success (< 36 months survival) and a higher risk of complications. Perineal urethrostomy carries a mean survival time of 34 months, and an approximately 52% success rate with the most common complication documented to be stricture of the stoma site (mean time to stricture of 65 days). Vescourethral anastomosis and bladder marsupialization (BM) carried a better long-term (> 12 months without reobstruction) prognosis in small ruminants of cases, with reported 60% to 84% success and stoma patency for several months postoperatively. Commonly encountered complications include urine scald, bladder mucosal prolapse, ascending cystitis, and stoma stricture. These sequelae often require lifelong monitoring, supportive care, and sporadic surgical interventions to enlarge the stricture stoma. Attempting to preserve normal anatomy is ideal; therefore, an attempt to resolve the urinary obstruction with TC with or without urethrotomy is always the preferred initial treatment unless there are major factors that suggest a different approach (ruptured urethra, ruptured bladder, reobstruction, or stricture). In that scenario, we recommend a PU or a modified proximal perineal urethrostomy to resolve the obstruction, leaving the BM as a salvage procedure.

This review provides evidence that treatment of obstructive urolithiasis in small ruminants carries an overall favorable prognosis for short- and long-term survival (up to 36 months). However, surgical intervention is frequently necessary, and complications such as persistent or recurrent urinary obstruction and stricture are common and can be expensive and sometimes difficult to treat.

In conclusion, small ruminant urinary obstructions are challenging and complicated conditions to treat, due to the multifactorial decision-making that involves realistic owner expectations, finances, technical skills, difficulty of procedures, number and location of uroliths, and intended use of the animal. Therefore, decision trees are useful to guide decisions in the treatment of urinary obstruction in small ruminants.

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Supplementary Materials

Supplementary materials are posted online at the journal website: avmajournals.avma.org