Urolithiasis Prevention and Treatment in Goats

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INTRODUCTION

Obstructive urolithiasis continues to be a significant medical problem in livestock species, particularly in small ruminants. Medical and surgical management of this problem in ruminants, camelids, and swine is well described in many texts and publications.[1,2] Overall successful management of individual patients is quite variable and complications with establishing short or long term urine excretion remain common. This presentation will discuss some of the challenges observed and concepts developed over the last 20 years of treating patients with urethral obstruction due to urolithiasis at Colorado State University

KNOW YOUR STONE

The type of urinary calculi present is often unknown at the time of presentation. However, the ability of the stone to be dissolved through acidification of the urine has significant impact on surgical approach and outcome if urethral stones are present. Magnesium ammonium phosphate (struvite) uroliths are generally soluble in aqueous solution with a pH of 5.5 to 6.5. Other urolith types including calcium carbonate, calcium oxalate, and silica are essentially non-dissolvable in physiological aqueous solutions. In review of the literature and discussion with clinicians across the country, the types of urinary calculi observed, particularly in small ruminant patients, seems to have changed over time and may be influenced by the geographical location, management and nutrition of the patient. At CSU, we see an overwhelming prevalence of non-struvite uroliths in obstructed small ruminants based on analysis of stones recovered at surgery or necropsy. This is similar to that reported by the Minnesota Urolith Center.[3] Magnesium ammonium phosphate (struvite) was identified as the most common urolith type in Boer goats in a different study.[4] In potbellied pigs, the most common stone reported was magnesium calcium phosphate.[5]

Table 1. Distribution of major uroliths in livestock identified at the Minnesota Urolith Center (1981-2007).[3]

Urolith	Cattle #, (%)	Goat #, (%)	Llama #, (%)	Sheep #, (%)	Domestic Pigs #, (%)
Calcium Carbonate	8 (3.7)	224 (42.6)	1 (4.2)	33 (29.7)	3 (3.2)
Calcium Oxalate	4 (1.8)	4 (0.8)	0	1 (0.9)	2 (2.1)
Calcium Phosphate (apatite)	17 (7.8	16 (3)	1 (4.2)	14 (12.6)	33 (34.7)
Magnesium Ammonium Phosphate (struvite)	73 (33.6)	19 (3.6)	2 (8.3)	16 (14.4)	18 (18.9)
Magnesium Calcium Phosphate	8 (3.7)	24 (4.6)	0	0	3 (3.2)
Magnesium Calcium Phosphate Carbonate	28 (12.9)	101 (19.2)	1 (4.2)	22 (19.8)	9 (9.5)
Silica	43 (19.8)	76 (14.5)	18 (75)	12 (10.8)	3 (3.2)

True commercial meat animals still seem to have a higher prevalence of magnesium ammonium phosphate (struvite) urolithiasis due to the high concentrate diet. Nutritional prevention of struvite urolithiasis in livestock can be successfully managed by reducing phosphorus (<0.25-0.30% DMI) and magnesium (<0.12-0.18% DMI) intake, and keeping the Ca:P ratio near 2:1. The importance of knowing if struvite urolithiasis is involved is because this is the only stone type that is readily dissolved by acidification of the urine. Thus, medical management is possible, and urinary acidification following surgical procedures can often successfully restore urethral patency. Struvite should be suspected if fine gritty material is palpable on the hairs at the end of the prepuce. If calculi are collected from the distal urethra during examination or from the urinary tract at surgery, a sample of the stones can be placed in acetic acid (vinegar) to quickly evaluate whether or not they are likely to dissolve with urine acidification.

Other urinary calculi including calcium carbonate, calcium oxalate, silica, or calcium phosphate are not likely to dissolve as readily with urinary acidification and must be small enough to be flushed through the urethra or they must be removed surgically in order to restore urethral patency. If this is not accomplished at the time of initial surgical intervention such as tube cystotomy, then persistence of urethral obstruction is common. This concept cannot be under stated as patients presented with struvite urolithiasis seems to be decreasing in frequency while the other stone types, particularly calcium carbonate in pet small ruminant populations, seems to be increasing. While struvite urolithiasis can be controlled from a nutritional standpoint, the risk factors and nutritional causes of calcium carbonate urolithiasis are not well understood. Excessive calcium urinary excretion likely plays a role, however the factors underlying calciuresis and calculogenesis are not fully understood and calcium intake is only one of many factors involved.

STABILIZE OR IMMEDIATE SURGERY? WHAT OPTIONS ARE THERE?

Many patients with urethral obstruction present with marked discomfort and are uremic with multiple electrolyte and metabolic disturbances. For these reasons stabilization of the patient is often indicated but must be balanced with the need to restore urine excretion. Since stabilization in part will rely on correction of azotemia and electrolyte imbalances, fluid therapy is often indicated. However, this results in obvious challenges if relief of urine accumulation and restoration of urine excretion is not achieved.

Patients that are significantly compromised and have marked or complete urethral obstruction may not be considered sufficiently stable for general anesthesia or surgery. This results in the challenging decision of how to relieve urine accumulation in a safe and effective manner while providing fluid and electrolyte support to stabilize the patient. If the bladder has already ruptured, uroperitoneum can be relieved by abdomenocentesis or placement of an abdominal Foley catheter for drainage and peritoneal lavage. If the bladder is intact, temporary relief can be provided by cystocentesis. However, the cystocentesis site is likely to leak as soon as the bladder becomes distended again. Percutaneous transabdominal catheterization of the bladder is described as a temporary procedure to provide bladder drainage and allow time to stabilize the patient or treat the urethral obstruction medically.[6-9] Methods include placement of a coiled or other self-retaining catheter (Bonanno Catheter, Becton Dickinson, Dewan Suprapubic Urodynamics Catheter, Cook Medical, Stamey Percutaneous Malecot Suprapubic Catheter, Cook Medical), Foley catheter through a percutaneous insertion sleeve (One-Step Suprapubic Introducer, Cook Medical, or Supra-Foley Introducer, Utah Medical Products, Inc.), Foley catheter with a needle stylet (Rutner Suprapubic Balloon Catheter, Cook Medical), or using a minimally invasive paralumbar approach[10] to place an infusion set tube into the bladder. The most common complications with these procedures are obstruction of the catheter, loss of placement within the bladder, leakage around the catheter, and intestinal perforation. These catheters will generally remain patent for up to 3 days allowing time for stabilization and the opportunity to perform surgery under more elective conditions.

DON'T NEGLECT DIAGNOSTIC IMAGING

Diagnostic imaging consisting of both ultrasound evaluation of the bladder and abdomen as well as radiographs of the bladder and urethra is helpful in confirming a diagnosis, establishing potential sites of obstruction, directing surgical intervention, and refining a prognosis. In particular, radiographic imaging is extremely helpful in identifying the location of calculi within the urethra and provides useful information to plan for surgery or to intervene post-operatively if urethral obstruction is not resolved.[11] Unless the urinary calculi are known to be struvite and will dissolve with acidification, the surgical procedure must plan on removal of all stones within the bladder and urethra in order to have the greatest likelihood restoring and maintaining urethral patency.

CHOICE OF SURGICAL PROCEDURE

Several surgical procedures for treatment are described.[1,2,12,13] Salvage procedures are often recommended for commercial animals (Table 1). These procedures are intended to provide temporary relief of urethral obstruction with low cost. However, there is a high incidence of recurrence of urethral obstruction within 12 months. The two main causes for the recurrence of urethral obstruction are stricture at the surgical site and re-obstruction by stones still present in the bladder. Presurgical radiographic imaging can help identify the extent of urinary calculi and may aid in determining the suitability of these procedures.

Table 2. Salvage and long term surgical procedures for urinary obstruction caused by urolithiasis

Salvage Procedures	Long Term Procedures
Removal of the Urethral Process	Tube Cystostomy
Perineal Urethrostomy	Tube Cystostomy with Urethrotomy
Urethrotomy	Modified Perineal Urethrostomy
Penile Amputation	Bladder Marsupialization
	Vesicopreputial Anastomosis

Tube cystotomy is generally recommended for pet or breeding animals to restore normal urinary function. Failures with this procedure are observed and may in part be related to the type of urolith and the ability for obstructing uroliths to be passed, surgically removed, or dissolved. In early descriptions of tube cystostomy, overall success rates were reported near 70%.[14] However, in our population at CSU, the success of tube cystostomy without surgical removal or urethral stones is less. The lower success rate appears to be related to the high prevalence of non-struvite urolithiasis and the difficulty to remove these uroliths from the urethra by flushing or dissolution with a low pH.

LEAVE NO STONE BEHIND

The observed failure to restore urethral patency following tube cystotomy has led to a more aggressive surgical goal of removing all bladder and urethral stones during surgery unless there is strong confidence that the uroliths are struvite. Accomplishing this goal is greatly aided by pre-surgical radiographs of the bladder and urinary tract. At CSU, we have combined a tube cystotomy and urethrotomy surgical approach in order to achieve the goal of removing all stones from the bladder and urethra in order to surgically restore urethral patency. Our current approach is to perform a cystotomy to remove uroliths from the bladder. A second perineal surgical approach is performed to assist in passing a normograde urethral catheter to locate and remove uroliths through one or more urethrotomies. Once the catheter is successfully passed to the end of the penis, a second catheter is attached and then pulled retrograde into the bladder. Urethrotomy incisions are closed with 4-0 or 5-0 absorbable suture. The cystotomy is closed and a routine tube cystotomy is completed. Key points that we have learned with this technique will be discussed.

TUBE CYSTOTOMY COMPLICATIONS

Post-operative complications are often encountered during the management of tube cystotomies. What appears to be persistent urinary discomfort is relatively common and may be partly related to both bacterial cystitis and mechanical irritation from the cystotomy tube. Bacterial cystitis is expected and managed by appropriate antibiotics. This bacterial cystitis will persist until the cystotomy tube is removed. The balloon of the cystotomy tube should not be over-inflated and 5 ml balloon catheters are adequate in most cases. However, partial filling of a 5 ml balloon increases the risk of collapse of the balloon and retraction of the catheter from the urinary bladder. The cystotomy tube should exit the body wall in a natural position for a normal sized bladder in the caudal abdomen. There is a tendency to exit the cystotomy tube more anteriorly at the time of surgery when the bladder is very distended. This should be avoided to minimize stretching of the bladder when it returns to a normal size. Care should be taken if the catheter is tunneled in the subcutaneous tissues because this can increase the risk of kinking and obstruction of the tube at the point where it exits the external rectus sheath.

RESCUE PROCEDURES

Surgical intervention may fail due to the inability to resolve urethral obstruction or development of urethral stricture resulting in re-obstruction, particularly in non-struvite urolithiasis. In these cases, rescue procedures such as the modified proximal perineal urethrostomy technique[12], vesicopreputial anastomosis[13], or prolonged maintenance of a cystotomy tube may provide adequate long term urine excretion and comfort for the patient

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Urolithiasis Prevention Recommendations:

- **Provide Fresh, Clean, Warm Water at ALL times**
    - Cold water can decrease intake during the winter
        - Make sure water does not freeze in the winter
    - Hot, stale water in the summer can also decrease intake in the summer
- **Provide Electrolyte water along with fresh water**
    - Use a commercial electrolyte mix
    - As a substitute for a commercial electrolyte mix, you can use a combination of non-iodized table salt and lite salt
        - 15g table salt and 15g lite salt per gallon of water
- **Increase salt (NaCl) Intake:**
    - Helps for all forms of urolithiasis
    - Use non-iodized salt
    - Free choice White Salt block
    - 2-5% Dry Matter Intake (DMI)
    - 0.4 to 1 g/kg BW/dy
    - Mixed with feed pellets or dissolved in water and sprayed on the hay.
    - You can also make a concentrated salt water solution and spray on the hay to be fed free choice.
- **Remove or Reduce Alfalfa hay from the diet and change to**
    - Oat Hay or
    - Grass Hay
    - Believed to be most important for calcium or silica based crystals by reducing calcium excretion and amino acid metabolism to oxalate.
- **Decrease Phosphorus, Magnesium and Potassium Intake**
    - Most important for struvite urolithiasis
    - Phosphorus, No More than
        - 0.25 to 0.30% DMI
        - 50 to 60 mg/kg BW/dy
        - More likely to be high in grain
        - High P intake is the most common cause of struvite urolithiasis
    - Magnesium, No More than
        - 0.12-0.18% DMI
        - 25 to 36 mg/kg BW/dy
        - More likely to be high in hay
        - High Mg intake is associated with struvite urolithiasis
    - Potassium
        - Between 0.5 to 1% DMI
        - High potassium is more common in legume hay (alfalfa, clover).
        - High potassium levels increase urine pH and promote struvite urolithiasis
    - Maintain Ca:P Ratio between 1.5 to 3.
        - Low Ca:P ratio is associated with struvite urolithiasis
        - High Ca:P ratio is associated with Calcium Carbonate and Silica urolithiasis
    - You will need to have a feed analysis for minerals done on all your feed to determine if these are in the appropriate level.
- **Restrict additional grain feeding**
    - Decreases phosphorus intake and may help control struvite crystals

- **Consider feeding a commercial feed**
  - Purina Lamb Show Ration
    - 0.5% NH_4Cl (urine acidifier)
    - 0.5% NaCl (increases water intake)
    - Without Antibiotics
- **Urine Acidifiers**
  - Urine acidification can help dissolve struvite crystals and stones.
  - The salts used in urine acidification also result in an increase in water consumption that can help dilute the urine and decrease crystal and stone formation.
  - Ammonium Chloride (NH_4Cl)
    - 0.5 to 1% DMI
    - 100 to 200 mg/kg BW/dy
    - Divide into at least two doses per day
    - Poor palatability. May be mixed with grain or mixed in Karo syrup or molasses and administered orally. Also can be dissolved in water and sprayed on hay
    - Dissolve 200g NH_4Cl with 500ml water and then mix with 500ml molasses (final concentration 200mg/ml). Administer at 0.25 to 0.5 ml/kg twice daily orally.
    - Titrate your dose to obtain a urine pH between 5.5 to 6.5. If the pH approaches or falls below 5, discontinue until the pH rises above 6 and then resume at a lower dose.
  - Uroeze Powder or Tablets
    - Canine prescription urinary acidifier
    - Flavored palatable amino acid base
    - 400 mg NH_4Cl per ¼ teaspoon, or tablet
    - Start at ¼ tsp or 1 tablet per 10 lb BW q12 hr and then titrate to a urine pH of 6-6.5.
  - Bio-Chlor
    - More palatable than ammonium chloride
    - Mix with grain or other feed
    - 50 lb bag about $15
    - Feed at 0.05 to 0.15 lb per 100 lb BW per day
      - 0.5-1.5 g/kg/dy
      - This is about 0.15 to 0.25 lb per head per day for adult sheep and goats
    - Alternative Solution
      - Dissolve 500g BioChlor (use a food scale) into 750 ml (about 3 cups) water and then add 250 ml (about 1 cup) molasses. This will give a total volume of about 1 liter (32 oz) of solution with a concentration of about 0.5g/ml.
      - Administer 1ml/kg body weight orally twice daily for an 8-10 day period once per month.
  - Monitor Urine pH
    - Goal between 5.5-6.5
    - This pH will readily dissolve Struvite stones. It will have little or no effect on dissolving other stones. That is one reason why the mineral analysis of the stones can be helpful.
    - Severe metabolic acidosis and death can occur when the urine pH approaches 5

- Purchase some pH paper that will read in the 5 to 8 range or wider to check urine pH while the animal is on treatment. The urine pH should fall below 6.5 but remain above 5.0. If the pH is >6.5, increase the amount administered. If the pH is near 5 or <5, decrease the amount.

Characteristics of Some Urine Crystals in Ruminants

Crystal	Urine Crystal Appearance	pH Where Commonly Found		
		Acidic	Neutral	Alkaline
Calcium Carbonate	Large yellow-brown spheroids with radial striations, or small crystals with spheric ovoid or dumbbell shapes.	-	+/-	+
Calcium Oxalate	Small colorless envelopes (octahedral).	+	+	+/-
Calcium Phosphate	Amorphous, or long thin prisms.	+/-	+	+
Struvite (Magnesium ammonium phosphate)	Three- to six-sided colorless prisms.	+/-	+	+
Silica	Round white stones.	+	+	+

<u>Urolith Analysis</u>:
Minnesota Urolith Center
University of Minnesota
College of Veterinary Medicine
Veterinary Clinical Sciences Department
1352 Boyd Avenue
St Paul, MN 55108
612-625-4221
https://www.vetmed.umn.edu/centers-programs/minnesota-urolith-center
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SHORT CASE SERIES

WILEY

Combined tube cystostomy and urethrotomy for the treatment of urethral obstruction due to urolithiasis in goats

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Abstract

Objective: To describe the treatment of goats with urethral obstruction secondary to urolithiasis by combining tube cystostomy and urethrotomy.

Animals: Eight male goats.

Study design: Short case series.

Methods: Medical records (September 2012–September 2017) of male goats treated for obstruction secondary to urolithiasis with tube cystostomy and urethrotomy were reviewed. Data collected included signalment, history, physical examination findings, diagnostic results, perioperative treatments, operative details, hospitalization duration, intraoperative and postoperative complications, urolith analysis, and time to restoration of urethral patency. Long-term follow-up (>12 months) was obtained by email or telephone interviews of owners or by clinical examination.

Results: Seven of eight goats were castrated males of various of breeds. All goats were tachycardic with urethral pulsation at admission. Uroliths were composed of calcium carbonate in four goats and silica in one goat. All goats regained urethral patency during hospitalization, and all were discharged alive from the hospital. Seven goats were alive at long-term follow-up. Postoperative complications included persistent urethral obstruction requiring a second urethrotomy 2 days postoperatively, premature dislodgement of the bladder catheter and jejunal obstruction secondary to adhesions, and recurrence of obstructive urolithiasis within the proximal perineal urethra requiring a second surgery 8 months later (1 each). Long-term outcome was good, with urethral patency beyond 12 months in six of eight goats.

Conclusion: Combining tube cystostomy and urethrotomy restored urethral patency in goats with urethral obstruction from uroliths. Although none of the complications seemed directly related to the urethrotomy, formation of abdominal adhesions and recurrence of urolithiasis affected long-term outcomes.

Clinical significance: Uroliths that do not dissolve in acidic urine may be more frequent in some practices. The combined approach of tube cystostomy and urethrotomy appears to successfully restore urethral patency with promising long-term outcomes.

1 | INTRODUCTION

Castrated small ruminants are reportedly predisposed to urethral obstruction that can present as a medical-surgical emergency.[1-3] Urolith obstruction commonly occurs at narrowings in the distal sigmoid flexure and urethral process.[4-6] Medical management of concurrent systemic effects of obstructive urolithiasis is crucial, but alone is often unsuccessful.[6] A review of urolith analyses in obstructed goats in our hospital from 2002 to 2017 found that 12 of 18 goats had calcium carbonate and only one had magnesium ammonium phosphate (struvite) uroliths, similarly to other reports.[7,8] Calcium carbonate does not readily dissolve in aqueous solutions at a pH that results from urine acidification. Calcium carbonate uroliths reportedly dissolve poorly in acidic urine,[9,10] so urine acidification before or after tube cystostomy may be unsuccessful in establishing urethral patency.

Surgical treatment options for obstructive urolithiasis in small ruminants include urethral process amputation, phallectomy,[11] perineal urethrostomy (PU),[5] modified proximal perineal urethrostomy (MPPU),[12] prepubic urethrostomy,[13] urethrotomy,[4,5] percutaneous tube cystostomy,[14,15] cystotomy, tube cystostomy,[4,11,16] vesicopreputial anastomosis (VPA),[17] and bladder marsupialization (laparotomy or laparoscopy).[18,19] Endoscopic laser lithotripsy has been reported to restore urethral patency.[15,20] Short-term survival after urethral obstruction surgery in small ruminants is reportedly 76% to 90%,[4,11] but persistent or recurrent urinary obstruction and other morbidities negatively impact long-term prognosis.[4,14,21] Complications associated with failure of various surgical approaches for obstructive urolithiasis can be significant, including death: nine of 25 goats that underwent PU or MPPU died of complications of urolithiasis within 4 months.[22] Twenty-two of 63 small ruminants undergoing tube cystostomy had surgical failure or recurrence of obstructive urolithiasis within 6 months,[23] and two of five VPA performed in goats had complications associated with urolithiasis within 7 months.[17]

This report describes the approach and outcome of combined tube cystostomy and urethrotomy for initial surgical correction of obstructive urolithiasis in goats. This combination may help improve rates of return to urethral patency and successful long-term outcomes with fewer surgical failures.

2 | MATERIALS AND METHODS

2.1 | Case selection

Medical records (September 2012–September 2017) of male goats treated for obstruction secondary to urolithiasis with tube cystostomy and urethrotomy were reviewed. Only goats that had complete urinary obstruction without prior surgical procedures to address obstructive urolithiasis other than urethral process amputation were included. Data retrieved included signalment, clinical signs, results of preoperative and postoperative examinations and diagnostics, surgical description, intraoperative and postoperative complications, hospitalization duration, antibiotic, analgesic, fluid and other medical therapies administered, urolith analysis when available, and outcome. Follow-up was obtained by telephone interview with the owner or by clinical examination. Owners were asked whether the goat had experienced any postsurgical complications including urethral stricture, cystitis, or reobstruction. If the goat had died, details of the death were requested.

2.2 | Perioperative preparation

Results of preoperative bloodwork to evaluate electrolyte and acid–base status prior to anesthesia were obtained for all goats. Preoperative radiographs were obtained at clinician discretion. Perioperative antibiotics were either ceftiofur alone (ceftiofur sodium or ceftiofur HCl 2.2-5 mg/kg intravenous (IV) or subcutaneous every 12-24 hours; off label; US Department of Agriculture minor food animal species, goats are exempt from food animal ceftiofur restrictions), or a combination of ceftiofur with potassium penicillin G (22 000 IU/kg IV every 6 hours) or procaine penicillin G (22 000 IU/kg subcutaneous every 12 hours) at clinician discretion. All goats received preanesthetic medication (morphine sulfate 0.1-0.2 mg/kg IV) and flunixin meglumine (1.1 mg/kg IV) when admission creatinine was normal. Anesthesia was maintained with isoflurane vaporized in oxygen delivered through a cuffed endotracheal tube.

2.3 | Surgical procedure

After goats had been anesthetized, they were positioned in dorsal recumbency with the perineum at the edge of the surgical table. The ventral abdomen and perineum were clipped. The surgical field was aseptically prepared (2% chlorhexidine or 7.5% povidone iodine), the prepuce was lavaged with dilute chlorhexidine or povidone iodine solution and saline, and the surgical field was draped from caudal to the xiphoid to just ventral of the anus. A 6- to 10-cm right or left paramedian celiotomy was performed, centered between the distal extent of the prepuce and the scrotum or scrotal remnant, avoiding the prepuce and penis. The bladder was isolated and partially decompressed by aspirating urine with a sterile 20 gauge hypodermic needle if required to facilitate exteriorization. Two stay sutures were placed in the ventral aspect of the bladder, and a cystotomy was performed. Urine was suctioned, and the bladder was lavaged with warm sterile saline solution. Calculi or crystals identified within the bladder were removed with thumb forceps or lavage and suction.

A sharp midline perineal incision was created beginning ~3 cm ventral to the anus overlying the region of the distal sigmoid flexure. The penis was examined, isolated, and partially freed from connective tissue by blunt dissection, and the urethral process was removed if still present. A 5- or 8-French polypropylene catheter was passed normograde into the urethra via the trigone of the bladder with manipulation and extension of the penis at the caudal pelvic brim and sigmoid flexure to aid passage of the catheter to the site of obstruction.

After the obstruction location had been identified, the penis and urethra were isolated, allowing palpation of the urolith within the urethra. A urethrotomy was created over the urolith for removal. Uroliths adherent to the urethral mucosa were removed with thumb forceps (Figure 1). After obstructing urolith removal, normograde passage of a polypropylene catheter was continued until the catheter exited the penis or lavage fluid could be seen exiting the penis, confirming urethral patency. In addition, a catheter was passed retrograde from the tip of the penis to the urethrotomy site. These catheters were used to lavage the urethra to facilitate complete removal of urethral obstructions (Figure 2). If lavage was unsuccessful at dislodging additional obstructing uroliths, the urolith was located by using the catheters and removed by using an additional urethrotomy. After establishing urethral patency, when it was possible, a 5- or 8-French polyvinyl chloride feeding tube (Covidien, Mansfield, Massachusetts) was passed retrograde through the urethra to the level of the urinary bladder or to the level of the urethral recess to facilitate identification of the urethral mucosa and closure of urethrotomy sites. Retrograde catheter passage was assisted by suturing the tip to the normograde catheter and pulling up the urethra. Indwelling urethral catheters were secured by suturing to the prepuce and left in place for 5 to 7 days.

FIGURE 1 Intraoperative appearance of a urolith removed via urethrotomy. This calcium carbonate urolith adhered to the urethral mucosa and was gently removed with thumb forceps

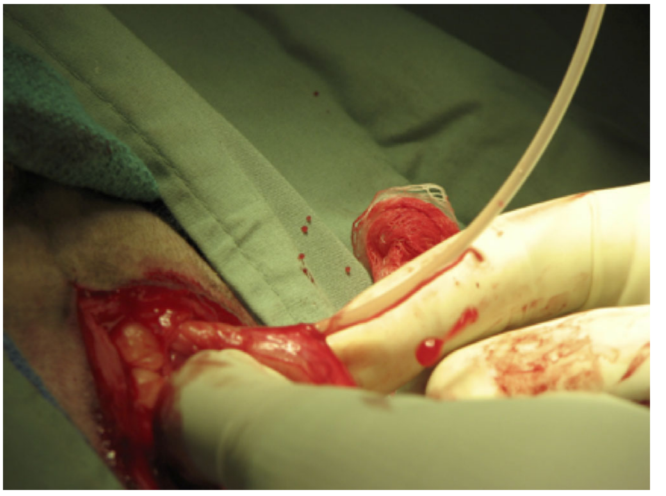

FIGURE 2 Operative photograph illustrating the use of a urethral catheter from the urethrotomy site to lavage the urethra and probe for additional uroliths

The urethrotomy sites were closed with No. 3-0 to 5-0 glycomer 631 suture (Biosyn; Covidien) in a simple interrupted or continuous pattern. The subcutaneous and skin layers were closed with simple interrupted or continuous patterns. The cystotomy site was closed in a simple continuous pattern oversewn with a Cushing's pattern. Tube cystostomy with a Foley catheter was then performed as previously described.[23] The abdomen was lavaged with sterile isotonic saline and active suction. The paramedian incision was closed in three layers.

2.4 | Postoperative care

Antibiotics were continued until 5 to 10 days after cystostomy catheter removal. Flunixin meglumine was initially administered at 1.1 mg/kg IV every 12 to 24 hours and maintained at 0.5 to 1.1 mg/kg IV every 12-24 hours for an additional 1 to 3 days. All goats received one to five morphine sulfate doses (0.1 mg/kg subcutaneous every 6 hours) for additional postoperative analgesia.

Perioperative intravenous fluid therapy was administered to all goats and was continued depending on clinical status, creatinine, and acid–base or electrolyte abnormalities. All goats had follow-up blood work performed, and those with elevated creatinine had blood work repeated 24 and 48 hours postoperatively.

Patency of the cystostomy catheter was monitored daily, and position within the urinary bladder was monitored via ultrasound as required. All goats were fitted with Elizabethan collars to minimize the potential of early unintended cystostomy catheter removal. Cystostomy catheters were left open for 3 to 7 days postoperatively to allow free drainage of urine from the bladder.

When an indwelling urethral catheter was present, it was maintained for 5 to 7 days postoperatively. In all cases, this indwelling urethral catheter was removed prior to urethral challenge. To assess urethral patency, the cystostomy catheter was intermittently occluded, and the goat was monitored for normal urination or signs of discomfort such as vocalizing, posturing, and straining to urinate without successful urination. Ultrasound was performed to evaluate bladder size and cystostomy catheter position when signs of discomfort were observed. When the bladder was enlarged, the cystostomy catheter was reopened and any expelled urine was collected to measure volume. If cystostomy catheter occlusion was tolerated, then the process was continued until successful normal urination was observed and the cystostomy catheter had been occluded for 24 hours or longer. When successful normal urination was attained, the cystostomy catheter balloon was deflated, and the catheter was removed. All urethral and four of eight cystostomy catheters were removed prior to discharge. Owners of goats discharged with catheters were given written catheter management instructions.

3 | RESULTS

Eight male goats (seven castrated, one intact) treated for obstructive urolithiasis with combined surgical tube cystostomy and urethrotomy were included. Breeds were two Nubian, two Alpine, and one each Boer, Nigerian dwarf, Pygmy, and mixed-breed. Median age was 30 months (range, 2.5 months to 6 years), and median weight was 66.6 kg (range, 9.8-105.3).

Presenting clinical signs were consistent with urinary obstruction in all goats including history of dribbling urine (4), anuria (4), stranguria (8), vocalizing (1), bruxism (1), and shivering (2) of 24 hours to two weeks duration. Urethral pulsation at digital rectal examination was documented in all goats. At initial presentation, bladder enlargement was visualized by transabdominal ultrasound in all goats, with excess free anechoic abdominal fluid in one goat.

At admission, all goats were neutrophilic (neutrophils $>6 \times 10^3/\mu L$; mean, $9.8 \pm 2.8 \times 10^3/\mu L$), hyperglycemic (glucose >75 mg/dL), and hypochloremic (chloride <109 mEQ/L) with normal serum potassium levels (mean, 4.5 mEQ/L; 3.8-5.15). Additional abnormalities included hemoconcentration (hematocrit >33%; 7), elevated creatinine (>1.5 mg/dL; mean, 4.3 ± 4.3; excluding one above 20 mg/dL measurable limit; 6), hypoproteinemia (protein <7.1 g/dL; 6), metabolic alkalosis (bicarbonate >25 mEQ/L; 5), leukocytosis (white blood cells $>14.5\ 10^3/\mu L$; 3), and hyponatremia (sodium <145 mEQ/L; 3). Elevated creatinine resolved within 48 hours postoperatively.

Preoperative radiographs were obtained for seven of eight goats; these radiographs confirmed radiopaque urolith presence and guided surgical planning in these seven goats. Intraoperative radiographs were obtained for three goats to evaluate for remaining radiopaque uroliths (one without preoperative radiography); no further radiopaque uroliths were identified in these goats.

All goats were considered stable enough for general anesthesia. Surgical intervention commenced within hours of initial presentation. Median anesthesia time was 239 minutes (range, 149-255) and median surgery duration was 155 minutes (range, 102-195), decreasing as more goats underwent the combined procedure. Three goats had previous urethral process amputation; one required preputiotomy. At the time of surgery, all goats had intact urinary bladders, but one had urethral rupture detected during catheter passage that was repaired with primary closure. The most common obstruction site was just proximal to the sigmoid flexure (6). The location and number of obstructing uroliths varied. Obstructing uroliths were in the distal sigmoid flexure in three goats and in the distal penile urethra in two goats, requiring additional incisions to access the penis and urethra, with two goats requiring two or three urethrotomies to establish urethral patency. Five goats had indwelling urethral catheters placed. Free-flowing urine was observed from the cystostomy catheter in all goats both in surgery and after anesthetic recovery. Uroliths collected at surgery were submitted for analysis in five of eight goats (4 calcium carbonate and one silica).

Median hospitalization duration was 9 days (range, 4-19). Goats with long hospitalization periods were kept for boarding at owner request. Two goats received ammonium chloride (50-60 mg/kg orally once daily) to facilitate urine acidification while awaiting urolith analysis results, decreasing urine pH to 5.5-6.5. Two goats received phenazopyridine (5 mg/kg orally every 8 hours) for bladder mucosal analgesia.

Postoperative antibiotics were transitioned to either ceftiofur crystalline free acid (6.6 mg/kg subcutaneous every 4 days; 4) or oral sulfadimethoxine (55-mg/kg loading dose, followed by 25 mg/kg orally once daily; 4) at clinician discretion. Nonsteroidal anti-inflammatories were continued for variable durations, with three goats transitioned to oral meloxicam (1 mg/kg orally once daily).

All eight goats survived to hospital discharge. Restoration of urethral patency was achieved in all goats. Median time to urine flow from the penile urethra was 1 day (immediately postoperative to 5 days). Signs of recurrent urethral obstruction were seen in one goat without an indwelling urethral catheter on the second postoperative day. A single urolith seen in the proximal urethra on radiography was removed through a second urethrotomy 3 days postoperatively. Another goat experienced dislodgement of the cystostomy catheter with decreased catheter urine flow 5 days after discharge, requiring emergency surgical catheter replacement 8 days postoperatively. The cystostomy catheter was found to be no longer within the bladder, and the balloon was no longer inflated, likely predisposing to dislodgement. This goat was euthanized because of suspected gastrointestinal obstruction prior to follow-up (survival time, 17 days). At necropsy, abdominal adhesions resulting in jejunal obstruction were identified. Notably, the cystostomy catheter was in place, bladder and urethrotomy sites were intact, and the urethra was patent.

Seven goats were alive >12 months postoperatively at follow-up, with median postsurgical survival of 20 months (range, 16-74 months). Six goats had no additional urinary obstruction episodes. One goat developed recurrent urolithiasis and urinary obstruction 8 months after his procedure and underwent VPA. In this goat, the obstructive urolith was located in the proximal perineal urethra, proximal to the prior obstruction and urethrotomy site.

4 | DISCUSSION

Combined tube cystostomy and urethrotomy resulted in urethral patency prior to hospital discharge in all eight goats. Furthermore, six of eight (75%) goats had no recurrence of urinary obstruction with this approach, and seven of eight (87.5%) goats were alive at long-term follow-up. This provides evidence that combined tube cystostomy and urethrotomy is a reasonable first-choice treatment of obstructive urolithiasis in goats and in other species that are disproportionately affected by calcium carbonate uroliths as a means to restore urethral patency and compares favorably to reports of other surgical approaches.

Surgical treatment of urolithiasis-caused urethral obstruction in goats is continually developing to address failure to establish long-term patency associated with current treatments. As a first-line treatment, urethral process amputation reestablishes urethral flow enabling bladder emptying in 50% to 60% of small ruminants,[6] but reobstruction occurs in 80% to 90% and within 36 hours in some.[4,6,14] Cystotomy can be used to remove bladder uroliths and may support normograde and retrograde lavage of the urethra. A clinical report of this treatment described restoration of urethral patency in seven of eight animals,[4] but others have reported concern regarding risks of urethral rupture and failure to reestablish urethral patency.[16] Tube cystostomy has a reported short-term success rate of 80% but a lower long-term successful outcome; recurrent urethral obstruction or surgical complications led to euthanasia in 16% to 28% of cases in two studies.[16,23] According to a report of clinical experience with percutaneous tube cystostomy, five of 10 goats experienced tube dislodgement, and all goats required a second surgical procedure within 6 months.[14] Minimally invasive tube cystostomy was reported as successful in eight of 10 goats.[24] Perineal urethrostomy, prepubic urethrostomy, MPPU, and urethrotomy with partial phallectomy have been reported to result in stricture formation and loss of breeding potential.[4,6,22,25] While VPA[17] reportedly has reasonable long-term success with 60% of procedures having stoma patency 12 months postoperatively, associated complications were reported; two of four goats developed ascending cystitis, and one of four goats developed stoma stricture resulting in bilateral hydronephrosis.[17] Bladder marsupialization in small ruminants reportedly has long-term success rates from 67% to 84%,[18,19] but animals experience continuous urine release and scald, which may be unacceptable to owners. Reported complications (bladder mucosal prolapse, ascending cystitis, and stoma stricture) can be life threatening.[12,17] Tube cystostomy, MPPU, and bladder marsupialization appear to have the highest likelihood of long-term success (>12 months without reobstruction),[12,14,16,18,19,23] but associated short- and long-term complications may not be acceptable for breeding males, outcomes may be unacceptable for pet owners, and all carry risks of persistent or recurrent urinary obstruction.

Obstructing urolith composition is important for successful medical management because struvite and apatite uroliths may dissolve after percutaneous tube cystostomy or tube cystostomy and urinary acidification. Struvite was previously reported as the most common form of urolith in pet goats (associated with high concentrate-based diets[4,19]) and in Boer goats.[26] However, calcium carbonate uroliths represent a large proportion of goat uroliths described in other reports.[7,8] Uroliths that do not dissolve in acidic solutions may decrease success of cystotomy alone or with urethral lavage, just as we report here that calcium carbonate uroliths were often adherent to urethral mucosa and required manual extraction.

While all goats in this series had urethral patency prior to hospital discharge, two had postoperative complications. Recurrent urethral obstruction occurred in the goat that had preoperative but not intraoperative radiographs. This underscores the benefit of radiography to document urolith removal in these surgical procedures. In select cases, perioperative radiographs can assist in surgery treatment planning, providing a baseline for confirmation of urolith removal and resolution of the obstruction.[10] In this case, intraoperative radiographs were not obtained, and surgical intervention was thought to have resolved obstruction because a urethral catheter was successfully passed from the bladder to the end of the penis; however, the urethral catheter was removed at surgery completion. It is possible that the catheter was pushed past a urolith or that a urolith remained in the bladder or urethral recess, causing obstruction after urethral catheter removal. Swelling at the urethrotomy site suggested urine accumulation, and absence of urethral urine flow on postoperative day 2 suggested obstruction. Radiographic evidence of a urolith in the proximal urethra justified a second urethrotomy. The euthanized goat had necropsy findings consistent with surgically attained urethral patency. Intra-abdominal adhesions are a potential complication after any abdominal surgery. Early repeat celiotomy for cystostomy tube replacement combined with catheter failure could have predisposed to peritoneal inflammation and adhesion formation. Allowing urethral healing by secondary intention might be an effective approach, but local urine leakage into surrounding tissue with pain and inflammation can result. The circumferential urethral injury caused by uroliths raises concerns regarding stricture formation.

Selecting a surgical technique to address urinary obstruction from urolithiasis is a multifactorial decision involving consideration of cost, technical procedural difficulty, obstruction location, number of uroliths, concurrent diseases, intended animal use, and owner expectations. We report successful management of goats with obstructing uroliths presenting to a single referral hospital. Geographic or regional differences may contribute to the predilection of urolith type, and outcome may differ among referral hospitals or may vary depending on surgeon. Combined tube cystostomy and urethrotomy for treatment of obstructive urolithiasis in goats affected by calcium carbonate uroliths appears successful in providing long-term urethral patency.

CONFLICT OF INTEREST

The authors have no conflicts of interest to disclose.

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