Obstructive Urolithiasis

Obstructive urolithiasis is the single most common urinary tract disease of small ruminants, with significant economic consequences. The 2001 USDA NAHMS sheep study reported that 20% of surveyed sheep operations had at least one case of urinary calculi in the previous 3 years.[2] Males are most commonly affected, but uroliths may form in females as well.

Uroliths are solid crystalline formations in the urine that are composed of organic matrix and organic and inorganic crystalloids that precipitate in supersaturated urine.[3] Factors affecting urine supersaturation include the rate of renal excretion of crystalloids, total body water balance, urine pH, and the presence or absence of crystallization inhibitors.[3] Metaplasia of uroepithelium, occurring as a result of vitamin A deficiency, may contribute cells and protein for nuclear formation.[4] Suture, tissue debris, blood clots, or bacteria also may serve as nuclear components initiating urolith formation.[3] Infection, however, is considered to be a minor factor in urolith formation in ruminants.

Urolithiasis is a multifactorial disease with diet, urine pH, and body water balance playing significant roles. Struvite (magnesium ammonium phosphate) and apatite (calcium phosphate) may be commonly seen in animals fed high-grain diets, while animals consuming legumes are predisposed to calcium carbonate uroliths. Silicate stones may be found in animals grazing silicaceous plants and soils in the western United States and Canada. Calcium oxalate stones may be associated with oxalate-containing plants. A significant factor in availability of urolith components and their binding ability is urine pH.[5] Struvite, apatite and calcium carbonate uroliths are known to precipitate in alkaline urine.[3,5] Struvite crystallization occurs only at a pH range of 7.2 to 8.4, whereas apatite stones develop at a urine pH of 6.5 to 7.5.[6] Calcium carbonate stones also tend to form in alkaline urine, but pH may have little or no effect on silicate or calcium oxalate uroliths. Total body water balance plays an important role in calculogenesis by its effects on urine volume and concentration. Such effects may be apparent in winter and during times of other systemic illness, when animals consume decreased volumes of water, thereby reducing urine output.

Uroliths may obstruct urine flow anywhere from the renal pelvis to the distal urethra, although the most common sites of obstruction are at the distal sigmoid flexure and in the vermiform appendage in sheep and goats (Figure 12-7, *A* and *B*). Obstruction at these sites may result in rupture of either the urethra or the urinary bladder.

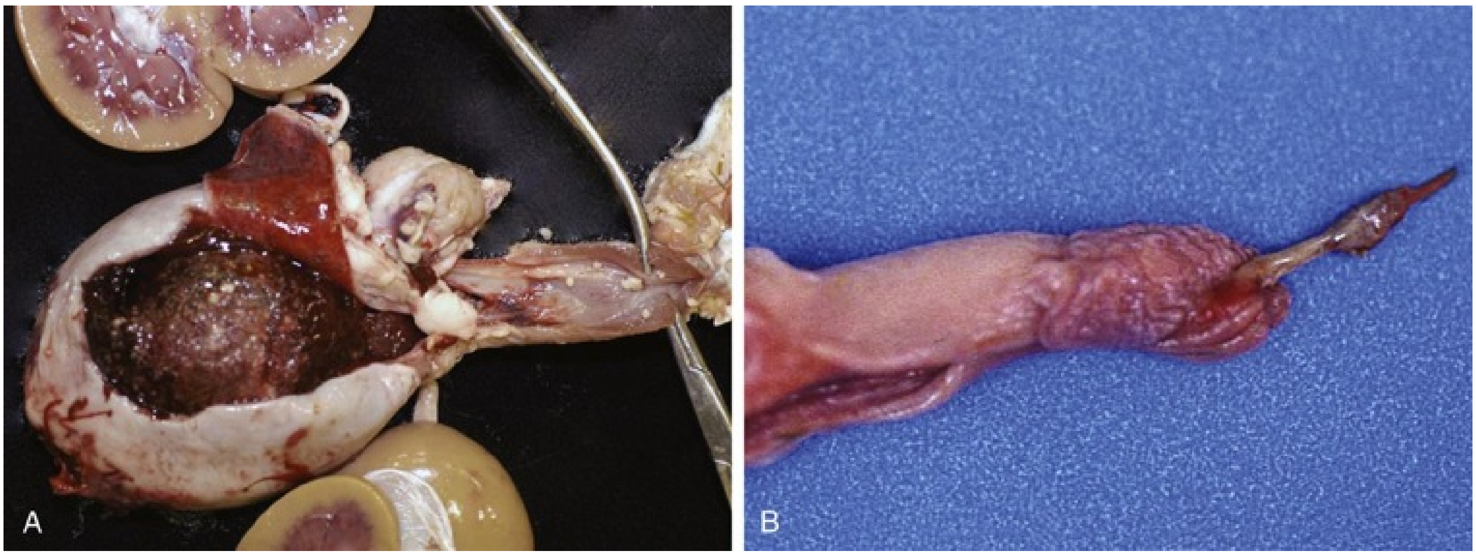
Although hematuria may be noted, urolithiasis without obstruction rarely results in clinical disease. Animals presenting with clinical disease related to urolithiasis are often obstructed and signs are dependent upon the degree of obstruction, location of the obstruction, and the duration of disease. Uroliths may not completely obstruct urine flow, yet the clinical presentation may be one of incomplete or even intermittent obstruction. Initial incomplete obstruction often becomes complete over time as a consequence of inflammation of damaged urethral mucosa. Clinical signs of urinary obstruction may range from nonspecific inappetance and lethargy to overt colic. Restlessness and persistent straining, repetitive posturing to urinate, and vocalization are common. Swelling around the prepuce or bilateral ventral abdominal distention may be noted with rupture of the urethra or urinary bladder, respectively.

Clinical pathology findings are related to the duration of obstruction and sequelae, such as uroabdomen and hydronephrosis. In a retrospective study of goats with urolithiasis, the most common abnormalities were azotemia and hypophosphatemia.[7] Animals also may have slight decreases in sodium and chloride, and elevations in potassium and a metabolic alkalosis.[7] Unlike monogastric species, the azotemia is often mild or may not be present early in the disease as ruminants have the ability to more effectively manage uremia. In addition, ruminants often maintain adequate phosphorus and potassium homeostasis through salivary secretions,[8,9] without experiencing the large increases of these analytes as seen in obstructed monogastric animals.

The principles of management for obstructive urolithiasis include establishing a patent route of urine excretion, providing analgesia, correcting fluid deficits and electrolyte derangements, decreasing inflammation, and preventing infection. The presence of the urethral diverticulum prevents passage of a urinary catheter retrograde from the urethral orifice to the urinary bladder. Retrograde catheterization or retropulsion of uroliths is not recommended, becausefurther trauma or puncture of the urethra is possible. Attempts at retropulsion of uroliths may result in overdistention of the urinary bladder as the stone is diverted into the diverticulum, allowing fluid to pass into the bladder, followed by the urolith's falling back into the urethra.

Occasionally, removal of the vermiform appendage (Figure 12-8) in male sheep and goats establishes a patent urethra; however, inflammation in the proximal urethra from passage of the uroliths may still prevent normal urination. Uroliths tend to occur in multiples in the urinary bladder, and in most animals with

Figure 12-7 A, The pelvic urethra from an 8-month-old male goat with urinary calculi. B, The urethral process of this buck was occluded by a urinary calculus. This was a postmortem finding.



(Courtesy Dr. John Roberts, Thompson-Bishop-Sparks Alabama State Diagnostic Laboratory, Auburn, Alabama.)

Figure 12-8 Removal of the vermiform appendage in a goat wether without clinical obstruction. A scalpel blade or sharp scissors may be used.


obstruction initially relieved by amputation of the vermiform appendage, recurrence with subsequent stone passage is typical. Relief of urinary obstruction often requires surgical intervention.

The systemic health of the patient is an important consideration in selecting drugs to facilitate treatment. Acepromazine (0.05 to 0.1 mg/kg IV or IM) has been utilized in the medical management of urolithiasis.[10,11] Unproven rationales for use of acepromazine have been to relax urethral tone through α-antagonistic effects on smooth muscle and relaxation of the retractor penis muscle. Acepromazine also may suppress the anxiety associated with the inability to urinate. Caution is indicated with use of phenothiazine tranquilizers in patients that may already be hypotensive and hypothermic. Diazepam (0.1 mg/kg by slow intravenous infusion) also may be used for urethral relaxation and as an anxiolytic. Xylazine (0.05 to 0.1 mg/kg IV or IM) or other α_2-agonists may be used in attempt to restrain the patient for examination of the penis and have excellent analgesic properties in ruminants. Caution should be exercised with use of xylazine before relief of the obstruction, because it promotes diuresis,[12] as well as enhancing hypotension. Lumbosacral epidural blocks using 2% lidocaine (1 mL/7 kg) may be used in place of sedation to relieve discomfort and aid in exteriorization of the penis (see Chapter 18).

Fluid therapy should be instituted as indicated by the clinical examination. After relief of the obstruction, diuresis is important to replace dehydration, reduce azotemia and flush the urinary tract. Normal saline (0.9% NaCl) is a good choice for intravenous fluid therapy, although additional electrolytes and acid-base abnormalities should be considered. If obstruction has been present for longer than 36 to 48 hours or if the animal has a ruptured bladder, potassium is likely to be elevated, and electrolyte panels are very helpful in guiding the correction of electrolyte and acid-base abnormalities. Potassium levels may be used as a marker for determining the degree of intervention, and high levels exert inhibitory effects on the heart, causing bradycardia. If the potassium levels are high, dextrose may be added to make a 2.5% to 5% solution (50 to 100 mL of 50% solution per liter of fluid) or insulin may be utilized to move potassium intracellularly, protecting the heart. The addition of 20 mL of 23% calcium borogluconate per liter of fluid can improve cardiac contractility, and atropine in a dose of 0.04 mg/kg can be used in bradycardic patients. Sodium bicarbonate can be used to correct acidosis and decrease hyperkalemia but should not be mixed with calcium-containing fluids. Nonsteroidal antiinflammatory drugs should be administered to decrease inflammation, thereby helping to prevent urethral stricture formation, but should be used with caution until adequate renal perfusion is attained. Broad-spectrum antibiotic therapy should be instituted to prevent or treat infection resulting from devitalized or inflamed urinary tissues or cavitational accumulation of urine. Beta-lactam antimicrobials (penicillins and cephalosporins) may be chosen, because they have good spectrum of activity and are excreted in the urine.

Of the many methods for relieving urethral obstruction from urolithiasis, those with practical application include vermiform appendage amputation, urethrotomy, urethrostomy, cystotomy, tube cystostomy, and urinary bladder marsupialization. Other methods including prepubic urethrostomy, extrapelvic and urethroprepucial anastamosis, buccal mucosal urethral grafting, and laser lithotripsy, are described much less commonly.[13-16] Relieving the obstruction by retrograde urinary catheterization is highly unlikely to be achieved in ruminants and pigs, owing to presence of the urethral diverticulum at the ischial arch of the penis.[17] On the occasions when an obstruction is cleared by retrograde catheterization, the relief is temporary, and some surgical treatment will be required to resolve the condition. In addition, dynamic and physiologic healing characteristics of the ruminant urethra are associated with a strong likelihood of luminal stricture formation as a result of trauma from calculi, attempted catheterization, or surgery (i.e., urethrotomy). Procedures such as urethrotomy and perineal urethrostomy are considered palliative or salvage treatments, because stricture formation at the surgical site within months is likely, resulting in reobstruction.[18] Surgery should, however, be considered the treatment of choice for long-term survival when the urethra has ruptured and significant damage to the distal portion of the penis and surrounding tissues has occurred as a result of urine accumulation. Perineal urethrostomy is not a viable option for maintaining intact breeding males. Tube cystostomy is a viable option for curative (long-term) relief of urethral obstruction, as well as for maintaining functional breeding males. Short- and long-term prognoses, complication rates, and reobstruction rates for each procedure have been recently reviewed.[19]

Vermiform Appendage Amputation

One of the first procedures to attempt relief of urethral obstruction is to visualize the vermiform appendage (urethral process) for evidence of lodged calculi. This is a narrow structure at the terminal urethra that is prone to calculi obstruction (see Figure 12-7, *B*). The patient is restrained in a sitting position while the penis is extended and visualized. Visualization of the penis may not be possible without general anesthesia in very young males, because diffuse preputial-penile attachments are still present before the effects of testosterone and maturity allow release. Sponge forceps may be used to extend the penis while the animal is under general anesthesia, which will allow the clinician to then carefully free the distal portion of the penis from the prepuce. Amputation of the vermiform is done with either a pair of Mayo scissors or a scalpel blade. Amputation usually is performed even if calculi are not visualized. Hemorrhage is expected but not profuse and may continue for some time (hours) owing to the effects of urine to delay coagulation (see Figure 12-8).

Urethrotomy, Urethrostomy, and Penile Transection and Transposition (With or Without Penile Amputation)- not ideal!

Urethrotomy and urolith removal can be attempted when stones are located by palpation, radiographs, or ultrasound. The distal sigmoid flexure is another common site where uroliths may lodge. A urethral incision may be made directly over the stone or in healthy urethra adjacent to it followed by urolith removal. Suturing the urethra is recommended by most investigators, but allowing healing of the urethrotomy site by second intention also is acceptable and much less technically challenging. Stricture formation is a high-risk complication of urethral surgery in small ruminants regardless of the specific technique employed.

Urethrostomy can be performed in different ways to allow for a prolonged or permanent stoma for urinary diversion. The most commonly performed technique often is referred to as a perineal urethrostomy. A combination of local and epidural anesthesia is provided and an incision is made on midline in the perineum somewhere between the ischial arch and dorsal to the sigmoid flexure, which is just dorsal to the scrotum. Our own preference is to incise the skin and subcutaneous tissue in as distal a location as possible, because the dissected penis will then be more mobile for urethrostomy with less tension. The distal urethrostomy also provides extra tissue proximally for surgical reconstruction should stricture develop. Alternatively, the approach can be at the level of the ischial arch, which may have the benefit of easier urinary bladder catheterization because the urethral diverticulum can be bypassed. Once the penis is dissected free from the subcutaneous tissue, the urethra can be incised longitudinally and a stoma sutured to the skin.

Alternatively, the penis can be transected and dorsal segment repositioned. Amputation of the penis provides a simple approach to relieving urethral obstructions. However, this procedure may not be cosmetically appealing, and strictures often appear within months after surgery. The surgery can be accomplished either with the animal under general anesthesia or with use of an epidural block. Many clinicians prefer to perform this surgery after administering epidural anesthesia to a sedated animal in sternal recumbency with the hindlimbs off the end of the table. A midline incision is made in the perineum dorsal to the sigmoid flexure at the point where the perineum turns ventrocranially. Careful sharp dissection is performed to expose the penis. The distal sigmoid flexure is identified and pulled to the incision site. If significant urine damage to the preputial tissues from urine leakage is noted, the entire distal penis often can be extracted from the wound with moderate pressure. The penis is avulsed from its preputial attachment.

A point on the penis 4 to 7 cm distal to the dorsal edge of the skin incision is chosen for the amputation site. The dorsal penile vessels are ligated dorsal to this point, and the retractor penis muscles are ligated and transected as far proximally as possible. The distal part of the penis is very difficult to remove (and removal is not recommended) if the surrounding tissues are normal. If the distal penis is not removed, the dorsal penile vessels should be reflected off the penis and left intact. The penis is transected as far distally as the perineal skin incision will allow. A wedge-shaped piece of tunica albuginea and the underlying cavernous tissue of the corpus cavernosum penis (CCP) are removed to allow a better closure of the CCP, thereby minimizing risk of hemorrhage with sexual stimulation of an intact male.

The transected CCP is closed with a simple continuous or continuous mattress pattern using 2-0 absorbable suture in the tunica albuginea surrounding the CCP. The urethra and tunica albuginea of the corpus spongiosum penis (CSP) are split longitudinally for 2 to 3 cm in order to spatulate the new urethral opening. The urethral mucosa is sutured to the tunica albuginea down each side and at the transected end of the penis with a continuous pattern using 3-0 absorbable material. This suture line seals the CSP and lessens hemorrhage during urination. A suture can be placed into the tunica albuginea at the mucosal closure near the transected end of the penis, around the dorsal aspect of the penis (opposite the urethra) and into the tunica albuginea again near the mucosa of the opposite side. The suture is then tied on the dorsal aspect of the penis. This suture creates a bigger opening of the spatulated urethra. The penile stump is secured to the skin with a mattress suture. A “bite” is taken through the skin where the penile stump will exit the incision. The next “bite” is into the tunica albuginea of the CCP and then the skin on the opposite side. The second half of the mattress suture is placed through the skin as is normally done ventral to the first “bite.” This suture will secure the penis in place, as well as directing the transected end of the penis out of the skin incision. The remainder of the skin incision is closed in a routine fashion of the clinician's choosing. Castration at the same time as for the penile amputation is prudent.[20]

Tube Cystostomy

Anesthesia

Surgical success in dealing with urinary obstruction largely depends on duration of disease, and correction of fluid and electrolyte derangements before or during surgery. Avoiding hypotensive drugs and rapid replacement of fluid volume probably are of primary importance. The electrolyte abnormalities to correct are hypochloremia, hyponatremia, and hyperkalemia. The severity of these electrolyte changes varies with duration and if the bladder has ruptured.

Potassium levels can be variable in ruminants, even with ruptured bladder. A ruptured bladder may quickly lead to hyperkalemic and acidotic in many species, but ruminants manage pH and electrolyte derangements better through salivary metabolism. Small ruminants (especially sheep), however, seem to be affected more often with the hyperkalemic acidosis syndrome, as seen in small animals and foals. This association probably reflects the duration of obstruction before recognition. Several anesthetic and preanesthetic protocols can be used to combat these life-threatening changes.

Tube cystostomy can be successfully performed in field situations with percutaneous introduction of the catheter. A method for percutaneous tube cystostomy and vesicular irrigation has been described.[21] Risks with this procedure include bowel perforation and increased risk of peritonitis [22] A disadvantage of this technique is that it does not allow normograde urethral flushing or removing stones through a cystotomy Therefore the tube probably will need to be left in the bladder longer before resolution of the condition is achieved. Guafenesin (5%) with 1 mg/mL of ketamine

added is adequate for intubation and also could be used to maintain a surgical plane of anesthesia.[23] For surgical induction or intubation, the dose of the "double drip" mixture is approximately 0.75 to 1 mL per pound of body weight. The onset of anesthesia is slow, and the drug should be administered slowly and to effect. In patients to be intubated, the use of a stylet to guide the endotracheal tube through the larynx and selection of a long laryngeal blade will facilitate the procedure.

General anesthesia is not essential for success in performing a tube cystostomy; however, it provides the surgeon more time to flush the bladder and attempt normograde catheterization for hydropulsion of stones from the urethra. Induction with "double drip" (guafenesin and ketamine) tracheal intubation with maintenance on a small animal anesthesia machine is easily performed in small ruminants. Alternatives to general anesthesia are a lidocaine epidural technique and local anesthesia with xylazine-ketamine sedation. Care should be taken with use of lidocaine in goats—the toxic dose is only 5 to 10 mg/kg. Xylazine also should be used with caution owing to its hypotensive and diuretic effects. The metabolic and electrolyte imbalances should be considered (hyponatremia, hypochloremia, and possibly hyperkalemia) and either monitored or empirically treated. Hyperkalemic animals can experience significant adverse cardiovascular effects with xylazine, which also sensitizes the heart to catecholamine-induced tachyarrhythmias (see Chapter 18).

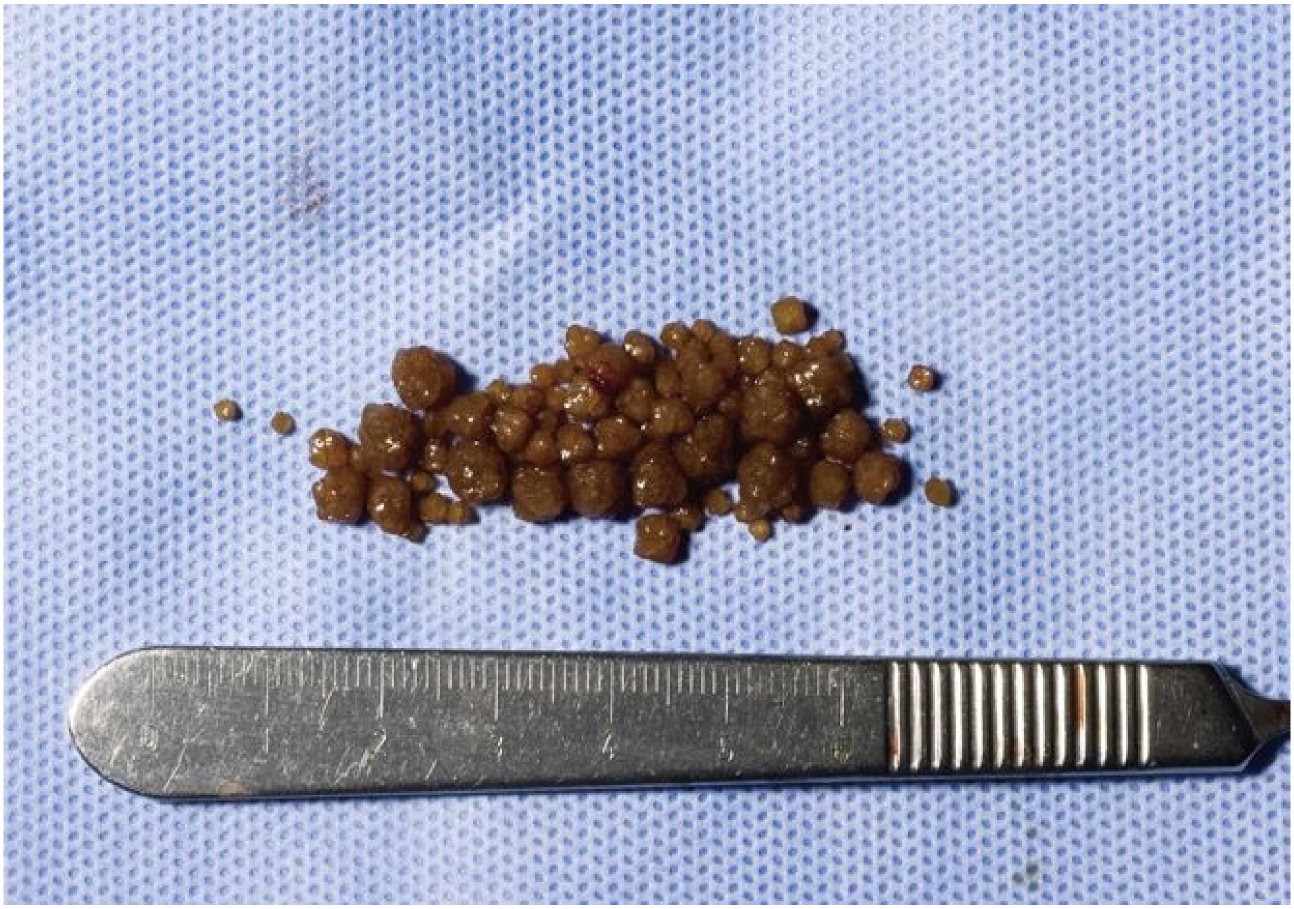
Approach

Laparotomy procedures are performed with the patient in dorsal recumbency. The abdomen is clipped and prepared for abdominal surgery. The recommended approach is paramedian, which avoids the penis. The incision should be approximately 15 cm long (anterior to posterior) with the posterior extent of the incision ending just anterior to the teat. Care is taken to avoid the caudal superficial epigastric vessels.

Cystotomy

The tip of the distended bladder is easily exteriorized through the body wall incision and packed off with moistened towels. Two stay sutures are placed in the bladder wall to maintain the bladder at the incision once it is decompressed. A sharp stab incision is made with a scalpel blade between the stay sutures, with care taken to avoid abdominal contamination with urine and calculi. Suction is very helpful in limiting contamination if available. The bladder incision is enlarged adequately to allow intraluminal palpation of the trigone of the bladder for stones. The bladder is then lavaged with saline to remove any stones, blood clots, and debris. A small spoon or scoop often is useful for removing stones (Figure 12-9). Next, the normograde passage of a polypropylene urinary catheter is attempted to flush stones from the urethra. It may be difficult to pass the catheter in many cases, but unsuccessful attempts do not predict failure to relieve urethral calculi. One technique that aids in placing a catheter in a normograde fashion is to place a finger in the trigone area and push the catheter under the finger into the urethra.

Figure 12-9 Uroliths removed through a cystotomy from a 2-year-old castrated Pygmy goat with obstructive urolithiasis. Calcium carbonate stones tend to be smooth and yellow-white to golden and resemble BB shot. Struvite crystals tend to be "sand-like" in appearance.



A syringe casing also can be used to fill the trigone. This technique more easily directs the catheter into the urethra, whereas it may curl in the trigone otherwise. Prolonged attempts at normograde catheterization should be avoided, to prevent excessive trauma to the urethral mucosa.

Tube Cystostomy

The tube cystostomy involves placing a Foley catheter through the abdominal wall and into the bladder to allow urine flow to bypass the urethra while the obstruction resolves and the urethral mucosa heals. The size of the tube should be large enough to permit free flow of urine and to allow passage of small blood clots without becoming obstructed. A stab incision is made in a caudal paramedian location contralateral to the laparotomy incision. The tip of the catheter is then passed through the abdominal wall. It is easiest to pass a hemostat from interior (peritoneum) to exterior (skin) and pull the catheter through. The Foley is then pleated through the omentum several times before being inserted into the bladder through a stab incision approximately 2 cm lateral to the cystotomy incision (Figure 12-10). The bulb is then filled with approximately 10 mL of saline. Some surgeons will then place a pursestring suture around the insertion of the catheter into the bladder. The cystotomy incision is then closed in a one- or two-layer inverting pattern. Finally, the laparotomy incision itself is closed. The portion of the Foley catheter exiting the abdomen should be anchored to the skin using a “finger trap” suture where it exits the body wall and as needed cranially with interrupted sutures, to prevent the tube from dragging on the ground (Figure 12-11).

Figure 12-10 Intraoperative photograph showing a distended, inflamed bladder in a 50-pound Pygmy wether with urethral obstruction. A Foley catheter has been placed through the abdominal wall, pleated through part of the omentum, and then secured into the decompressed yet still inflamed bladder with a purse string suture.

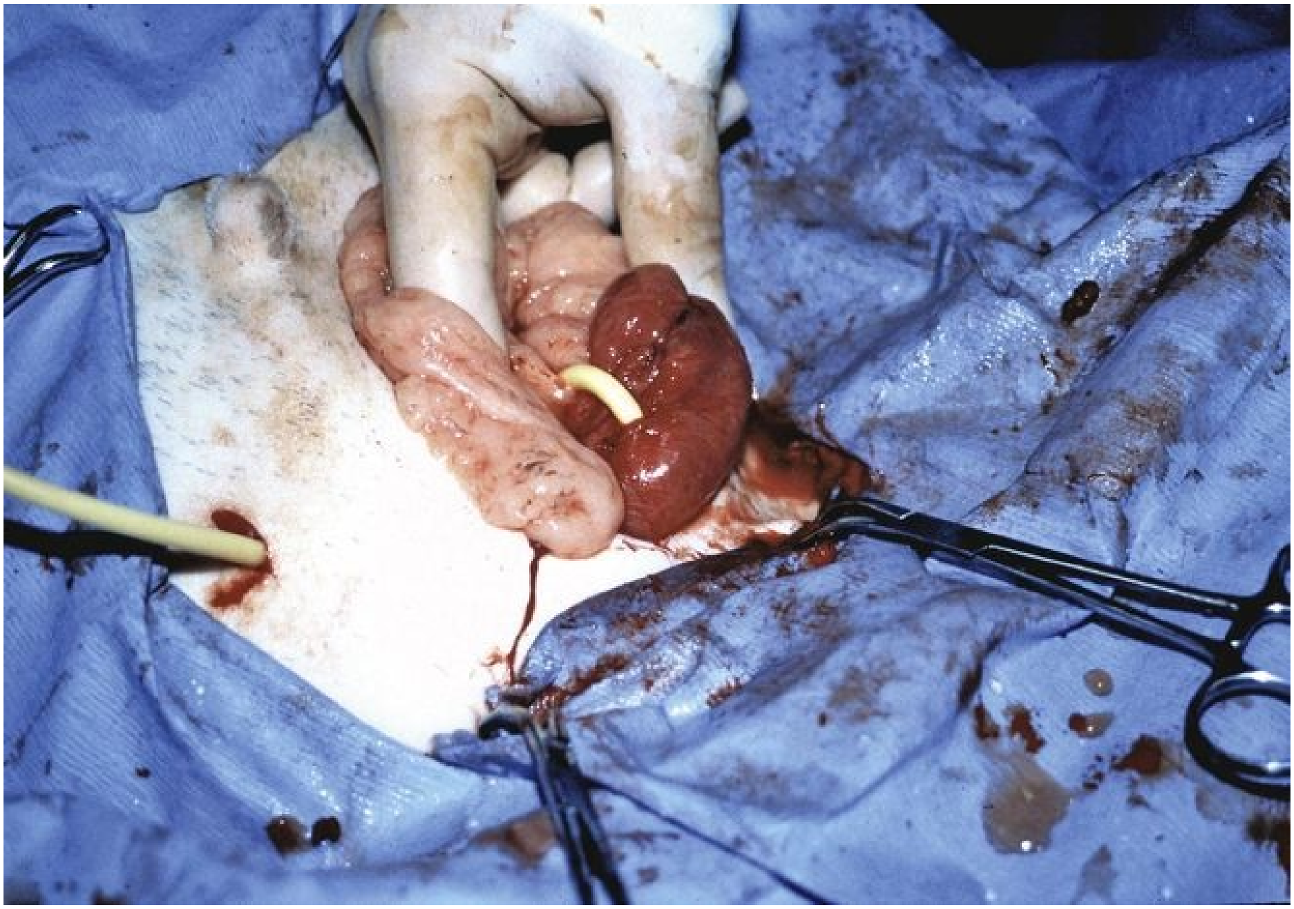
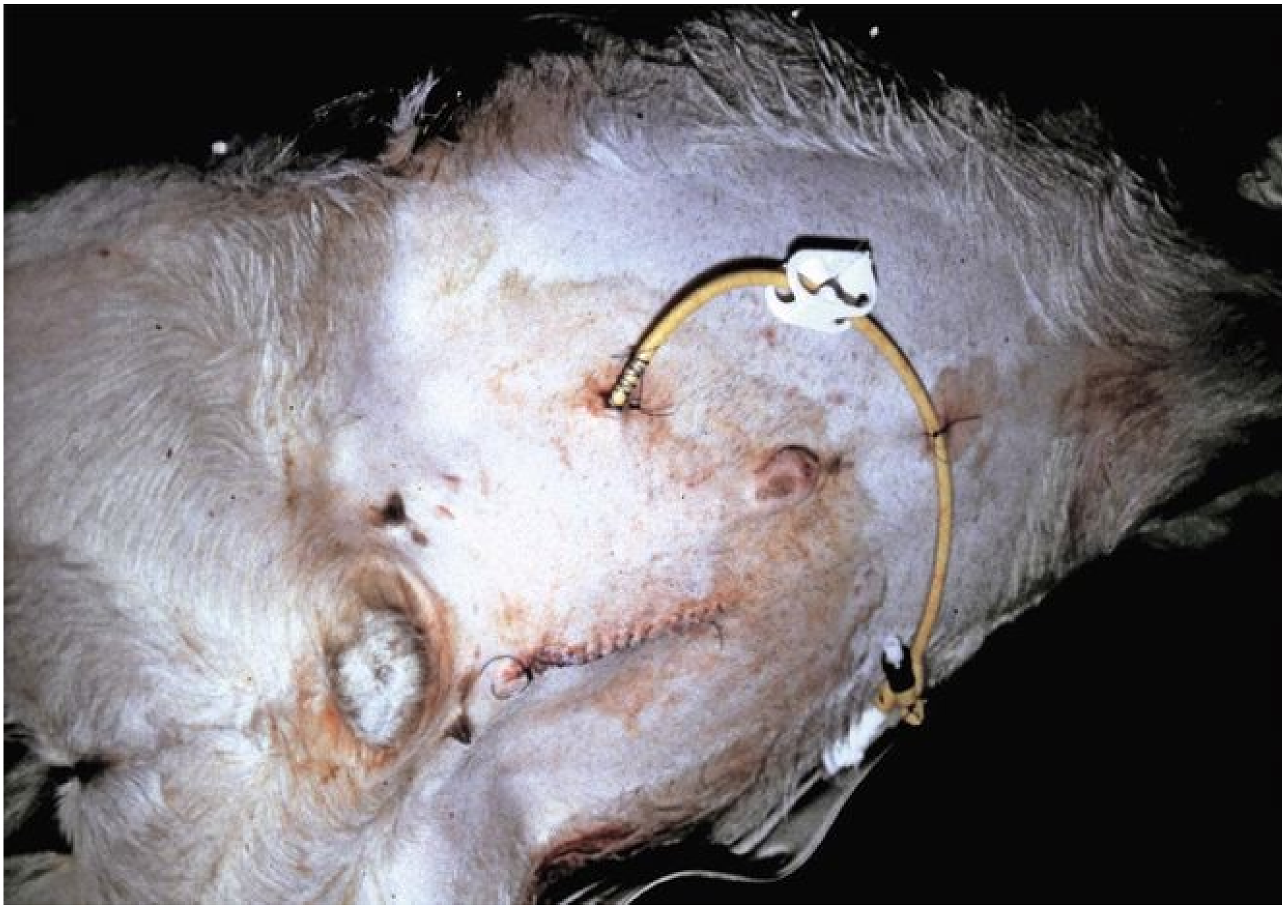


Figure 12-11 An immediate postoperative photograph of the Pygmy wether, showing the left paramedian abdominal incision closed with a continuous suture pattern and the Foley catheter exiting the body wall in the right paramedian area.



Postoperative Care

An Elizabethan-type collar can be placed on the patient to prevent chewing or dislodging the Foley. The Foley catheter should be tested for urethral patency 3 to 4 days after surgery, as follows: Obstruct the catheter by clamping it off, and monitor for urination or evidence of patient discomfort indicating persistent obstruction. If the animal becomes uncomfortable, the clamp is removed to allow urine drainage through the Foley. This process is repeated until the patient is able to urinate comfortably with the Foley occluded for 48 hours, at which time the Foley is removed. The Foley is removed by simply cutting any retention sutures, deflating the bulb, and pulling the catheter out of the bladder and withdrawing it through the skin. The surgeon should be cognizant that the clamp occluding urine flow through the Foley also prevents saline flow from the bulb, so it is important to unclamp the catheter before attempting to decompress the bulb. Regardless of when the animal urinates normally, the Foley should be left in place at least 7 days to allow formation of a fibrous tract around the catheter from the bladder to the body wall. This will prevent urine from diffusely filling the abdomen while the catheter site in the bladder heals. Urine leakage from the insertion site should cease with initial healing. A healing period of approximately 14 days is typical before the patient is able to urinate, even if, as reported in some instances, urethral calculi were present after surgery. However, tube retention may be necessary for even longer. The success rate for long-term cure (beyond 1 year) was approximately 70% in one retrospective study.[19]

Potential complications from urethral obstruction are hydronephrosis, cystitis, pyelonephritis, atonic bladder from overdistention, urethral stricture due to trauma from the calculi, failure to pass the obstruction, and erectile dysfunction in breeding males secondary to damage to the CCP.[19,24] The potential complications should be discussed with the client before initiation of treatment.

Urinary Bladder Marsupialization- not ideal!

Urinary bladder marsupialization provides direct drainage of urine from the bladder. A paramedian approach is made similar to tube cystostomy. When an empty or contracted bladder is anticipated, the selected approach should be more caudal than for a tube cystostomy The bladder is localized and the apex is sutured to the body wall and skin at a 3- to 5-cm paramedian incision site contralateral to the laparotomy incision. The seromuscular layer of the bladder is secured to the external rectus sheath; then the bladder is opened and the mucosa is sutured to the skin. Interrupted or short continuous segments of absorbable suture are used to create this stoma for permanent drainage of urine (Figure 12-12). Problems may arise with localized or ascending UTIs and urine scald, and obstruction of the stoma is possible owing to bladder mucosal proliferation and prolapse.

Nonsurgical Therapy

The use of Walpole's solution (sodium acetate and glacial acetic acid) has been published as an alternative therapy for obstructed cases with an intact urinary bladder in which surgery is not elected.[25] The procedure involves sedation of the animal and performance of ultrasound-guided cystocentesis to withdraw urine, then infusing 50 mL of Walpole's solution in to the bladder.

Figure 12-12 Immediate postoperative photograph of a 2-year-old castrated Pygmy goat with obstructive urolithiasis. A bladder marsupialization has been performed with the animal under general anesthesia in dorsal recumbency. For orientation, the preputial orifice is to the *left* and the rudimentary teats are to the *right*. The skin at the left paramedian laparotomy site has been closed with a simple continuous suture pattern. The bladder mucosa has been sutured to the skin edge to the right of midline in a simple interrupted pattern.

The solution is allowed to remain in the bladder for 2 minutes, followed by withdrawal of urine and pH testing. This procedure is repeated until the urine pH is 4 to 5; sufficient urine must remain in the bladder to maintain the cystocentesis needle in place. Reportedly, 80% of obstructions are relieved in the short term with use of this method, but approximately 30% of those animals subsequently experienced reobstruction after discharge

Walpole's solution also can be used to dissolve stones in cases treated by tube cystostomy. It is infused into the bladder through the Foley catheter, which is then occluded to retain the solution in the bladder. This is frequently done twice a day, with the catheter remaining occluded for up to 30 minutes so long as the animal is comfortable. A more aggressive approach with the pH testing as just described also may be used.

Once the obstruction is relieved, dietary and management modifications should be instituted to prevent reoccurrence in the individual animal and in the herd. Risk factors addressed in preventive strategies include high dietary phosphorus relative to calcium, high dietary magnesium, and low fiber content of rations, as well as low urine output and alkaline urine. Additional factors including selective grazing and castration timing may be addressed as well.

Dietary and Medical Management and Prevention

An elevated level of phosphorus in the diet, with a calcium-to-phosphorus ratio less than 2:1 increases the excretion of phosphorus in the urine and provides an

ion to bind to organic matrix.[26] Increasing the level of calcium in the diet markedly decreases the incidence of urolithiasis, probably owing to competition with phosphorus for intestinal absorption and matrix binding.[26] Phosphorus should not make up greater than 0.6% of the total ration,[5] and it is recommended that a 2.5:1 or 2:1 calcium-to-phosphorus ratio be maintained, with the use of calcium salts if necessary.[26]

Calcium oversupplementation should be avoided, because increased calcium excretion in the urine may contribute to calcium-containing uroliths. High phosphorus levels are present in grains, particularly sorghum, wheat, corn, milo, and oats. A reduction in phosphorus excretion into the urine also is desirable. Excessive dietary levels of

phosphorus excretion is greater in animals fed pelleted rations as compared with meal-type rations,[27] owing to a decrease in saliva production, and therefore a pathway for excess phosphorus excretion. Increases in the roughage component of diets are important from this standpoint as they increase the amount of saliva that must be produced for proper mastication. Particularly in the case of struvite stones, but also with apatite stones, an increase in magnesium excretion into the urine is contributory to crystallization. It is recommended that magnesium not exceed 0.6% of the total ration of ruminants.[5]

Increasing water intake and urine volume is an important preventive measure for urolithiasis. The provision of

Increasing forage versus grain in the diet of animals at risk for urolithiasis has many benefits. Grain results in increased magnesium, phosphorus, and peptides in the urine, and forage consumption encourages saliva production for phosphorus excretion, potentially reduces magnesium uptake, reduces overall grain consumption, and increases water intake. Legumes and their hays should be avoided, because they contain high levels of calcium and are associated with calcium carbonate urolithiasis (see Chapter 2).

adequate palatable water at desirable temperatures according to the ambient environment is desirable.[5] Ruminants demonstrate a reduction in water intake for grain feeding over roughage feeding. Additionally, the feeding of intermittent meals may cause shunting of body water into the rumen owing to increased osmotic pull from generated volatile fatty acids, resulting in a decrease in urine output. This possibility has led to the

recommendation that ruminants be fed ad libitum to maintain urine output.[5]

The role of urine pH in urolithiasis is well documented; urine pH goals of 5.5 to 6.5 are recommended, based on the solubilities of the common stone compositions. Owing to their ability to alter acid-base balance and body water balance, salts have been widely used and recommended for the prevention of urolithiasis. Anionic salts containing primarily chlorides have been popular and used extensively, because they reduce urine pH, increase urine output, and ultimately help prevent urolithiasis. Sodium chloride (1% to 4%), calcium chloride (1% to 2%), and ammonium chloride (0.5% to 2%) traditionally have been added as percentages of rations to increase water intake and produce acidic urine, with inconsistent results. The traditional addition of these salts as a simple percentage of the diet without consideration for the components of the total ration commonly leads to inconsistent and unsuccessful maintenance of a low urinary pH. Dietary cation-anion difference (DCAD) is a concept based on the strong ion difference theory and the effects on the body of dietary concentrations of the major physiologic cations and anions, represented by the formula ([Na+] + [K+]) - ([Cl-] + [S]) = mEq/kg of feed. With increased anions in the diet, the feed has a more negative DCAD, which produces a metabolic acidosis and aciduria in the animal. Few controlled studies for target DCAD levels currently exist, but a DCAD of 0 mEq/kg appears to achieve urine pH of less than 6.5 in both intact and castrated goats.[28,29] To accurately assess the efficacy of salts in the diet, whether DCAD is balanced or not, owners should be encouraged to periodically assess urine pH at home or on site.

we recommend the use of soy chlor to create this lower pH

Castration is significantly associated with the development of obstructive urolithiasis,[7] and early castration is thought to reduce the positive influence of testosterone on urethral diameter, as well as diminishing normal preputial-to-penile attachments that are present in the neonate. Delaying castration in pet animals may serve to increase urethral diameter, as well as increasing the ability to extend the penis for examination. A 2.5-fold increase in cross-sectional urethral diameter at the level of the distal sigmoid flexure was noted when castration of lambs was delayed from 2 weeks to 3 months of age.[30] When castration was delayed to 5 months, an 3.5-fold increase in urethral diameter was seen.[30] Other considerations may include prophylactic removal of the vermiform appendage in young animals and limiting the grazing of males on silicaceous pastures.