Urolithiasis in Small Ruminants: Surgical and Dietary Management

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Introduction

Urinary calculi, or uroliths, are concretions of solid mineral and organic compounds that cause disease through direct trauma to the urinary tract and obstruction of urinary outflow. The urethral process is the most common site of obstruction in sheep and goats; in those whose urethral process has been amputated, the distal aspect of the sigmoid flexure is the usual site for blockage.[1] In camelids, uroliths tend to become lodged at or distal to the distal aspect of the sigmoid flexure. Multiple calculi are usually present in the urinary tract of affected small ruminants.[1]

History and Clinical Signs

The sources of discomfort in acute urethral obstruction appear to be traumatic injury to the urinary tract epithelium and bladder distention following obstruction. However, the presenting complaint provided by the owner or caretaker may have little apparent relation to urinary tract disease. In a case series of 94 cases of urolithiasis admitted to the Veterinary Medical Teaching Hospital at the University of California at Davis, anorexia and bloat were the most common primary clinical complaint at admission.[1] Owners of affected animals frequently misinterpret these clinical signs as being reflective of an acute gastrointestinal disorder. It is possible that the mild bloat that seems so common to these cases occurs as a result of activation of the sympathetic nervous system; in other words, the painful abdominal process results in rumen atony. Owners of camelids appear to commonly misinterpret stranguria as tenesmus, as several camelid urolithiasis cases in the author's practice received previous treatment for colonic impaction prior to referral. Consequently, if the patient is an ill male or castrated male ruminant, camelid, or pig, it is critical to determine if that animal is capable of urination. Prior to veterinary examination, males or castrated males with compatible historical data should be moved to a dry, unbedded area so that urine production can be assessed. The African Pygmy goat may be predisposed to urinary tract obstruction, as this breed had significantly higher representation in urolithiasis admissions than other breeds in a 1995 study.[1]

Early on, the animal postures repeatedly to urinate, and the tail may be seen to "pump" up and down as the animal strains to void urine. The abdominal musculature may heave with the forceful attempts to void. These forceful voiding attempts may result in frequent passage of small volumes of urine or no urine at all. As bladder distention progresses, the animal may tread, stretch, and kick at its abdomen. Vocalization is common in goats experiencing pain during urination attempts. Blood or crystals may be adhered to the preputial hairs.

Confirmation of the diagnosis can be achieved by deep abdominal palpation in sheep and goats. Using the fingertips of both hands placed in the flanks, the examiner gently presses each hand toward the midline, as shown in Figure 1 . A firm, spherical mass can be palpated in the caudal abdomen in obstructed sheep and goats that have an intact bladder. Given that camelids have a less pliant abdominal wall than sheep and goats, confirmation of a diagnosis of urolithiasis in llamas and alpacas requires transrectal or trans-abdominal ultrasonographic examination. Ultrasonographic examination of the perineum may be used to determine the location of the obstruction, if this information is helpful in selection of the surgical procedure.

Signs of pain usually subside upon rupture of the bladder or urethra. The empty bladder is no longer palpable. Anorexia and lethargy progress with these complicating conditions and are accompanied by progressive ascites or ventral abdominal wall edema with bladder or urethral rupture, respectively. Abdominocentesis and abdominal fluid creatinine measurement can be used to confirm the presence of uroperitoneum.

Surgical Treatment of Urolithiasis

Preoperative Evaluation

Whenever possible, the author prefers to perform ultrasonographic evaluation of the kidneys of animals whose clinical history is suggestive of prolonged disease, defined as signs of obstruction for greater than 24 hours duration. Detection of severe hydronephrosis (complete absence of renal cortical tissue) would warrant a grave prognosis and obviate the decision for surgery. Figure 2 shows the transabdominal ultrasonogram from a 3 year-old intact male alpaca with a history of urinary obstruction of 2.5 days duration. Note the presence of renal pelvic dilation but the presence of visible cortical tissue; the latter finding prompted continuation with treatment with a guarded prognosis for long-term renal function. Azotemia did resolve in this animal after surgery.

Fig. 2

The animal suffering from urolithiasis may be relatively stable if the disease is detected early in its course. More advanced signs of hypovolemic crisis may develop if the animal has developed severe pre-renal azotemia and/or electrolyte imbalances, which usually accompany prolonged (>24 hour) history of disease, or if the animal suffers from uroperitoneum and the associated electrolyte and acid-base imbalances.

Intravenous fluid therapy is indicated in cases of moderate or severe dehydration or if any of the above conditions exist. Physiologic (0.9%) saline solution is the fluid of choice for animals with uroperitoneum because these animals are typically hyponatremic and hypochloremic. Owing to the variability of serum potassium concentration in ruminants with obstructive urolithiasis, supplementation of potassium salts to polyionic fluids should be performed only if the animal is determined to be hypokalemic. Animals with chronic impairment of urine egress, metabolic acidosis, and/or uroperitoneum appear to be at risk for hyperkalemia. Hypocalcemia may also occur secondary to bladder rupture, and saline can be supplemented with calcium salts.

If general anesthesia is to be used, dehydration and severe electrolyte imbalances should be corrected prior to induction; normalization of blood sodium and potassium concentrations is of central importance. This guideline should be followed even if intravenous fluid therapy may result in bladder rupture. Bladder rupture can be repaired; anesthetic complications associated with urolithiasis are often difficult to correct. The author prefers to perform cystocentesis in obstructed small ruminants that require large-volume fluid therapy prior to anesthesia. While urine leakage through the cystocentesis site inevitably results in uroperitoneum, the site of cystorrhexis is made focal and is far easier to repair than spontaneous bladder rupture. Preoperatively, any urine in the abdominal cavity can be slowly drained with a trocar or large-bore indwelling catheter. Drainage of urine reduces pressure on the diaphragm, which is critical for animals restrained in lateral or dorsal recumbency, and slows the progression of azotemia and electrolyte imbalances.

The normal epithelial defenses of the lower urinary tract are damaged in urolithiasis, making the animal more prone to ascending urinary tract infection. Antibiotic therapy, therefore, is a sound choice if treatment is elected. Beta lactam antimicrobials or sulfonamides are appropriate choices. Aminoglycosides and fluoroquinolones are also concentrated in the urine, but their use is limited in food animals, owing to prolonged residues and federal laws limiting use, respectively.

Issues Related to Informed Client Consent

Owner consent for surgical treatment should include a discussion of the following potential complications: 1) Cardiac or respiratory arrest during sedation, anesthesia, or restraint / recumbency; 2) renal failure secondary to hydronephrosis, even if ultrasonographic evaluation reveals normal renal structure); 3) intraoperative and postoperative hemorrhage caused by the platelet and coagulation cascade dysfunction that can accompany uremia; and 4) formation of additional uroliths and/or movement of renal uroliths into the urethra, causing recurrent urethral obstruction postoperatively. The latter complication appears to occur in a significant number of cases. In a 1996 study, 10 of 23 cases successfully unblocked by various surgical methods developed recurrent urethral obstruction within a few months to years after discharge.[7] Owner compliance with dietary recommendations was not determined but was subjectively assessed as inconsistent.[7] Therefore, it is critical that the owners understand the inherently high recurrence rate associated with surgical management of urolithiasis in small ruminants. Adherence to preventive dietary measures may limit recurrence, but supportive data is currently lacking.

Urethral Process Amputation

The urethral process should be examined in all cases of suspected urolithiasis in small ruminants. Sedation and/or lumbosacral epidural anesthesia facilitate penile extrusion. Although it produces sedation and is a potent analgesic, xylazine is not recommended for use in ruminants with urolithiasis, as its diuretic effect may worsen bladder distension if urethral obstruction is complete. The author prefers diazepam (0.1 mg/kg IV, slowly) to provide sedation without analgesia.

Once sedated, the sheep or goat should be propped up on its rump. The examiner should grasp the penis through the skin at the base of the scrotum and force the penis cranially. As the glans protrudes from the prepuce, it can be grasped with a dry gauze, and the penis can be exteriorized completely. If obstructed, the urethral process can be amputated at its base, near the glans of the penis. Removal of the urethral process has no adverse effect on breeding ability or fertility.

In larger rams and bucks, resistance to penile extrusion may limit one's ability to visualize the urethral process. Lumbosacral epidural anesthesia provides complete analgesia for penile extrusion and eliminates resistance to extrusion caused by the retractor penis muscle. One ml of 2% lidocaine per 5 kg to 10 kg of bodyweight is injected into the epidural space at the lumbosacral junction. The total dose should not exceed 15 ml in any small ruminant. Motor blockade of the hindlimbs lasting 1-3 hours will occur, and a well-bedded area should be available for larger patients to allow for safe recovery of motor function. If the sacrococcygeal space is palpable, 1-2 ml of 2% lidocaine can be injected at this site for perineal analgesia, although in the author's experience, penile motor blockade occurs far less predictably than with lumbosacral anesthesia.

Another possible limiting factor for exteriorization of the penis a the persistent frenulum. The frenulum is the normal anatomic attachment that exists between the penis and the preputial mucosa. It normally breaks down at puberty. This typically occurs at 4-8 months of age in sheep and goats and 1.5-2.5 years of age in alpacas. If present, the frenulum will effectively prevent exteriorizing the penis. The persistent frenulum may be most problematic in prepubertal animals with urolithiasis, animals castrated at a young age, and (rarely) the intact yearling or two year-old ram or buck. If a persistent frenulum is present, one may have to anesthetize the animal and force the penis out of the prepuce for examination.

Immediate restoration of urethral patency (a.k.a. urine voiding and emptying of the distended bladder) has been reported to occur in 37.5%[1] to 66%[4] of amputations. However, if urethral patency is restored with this procedure, it may be maintained only for hours to a few days, as additional calculi in the bladder or urethra often cause recurrent urethral obstruction. This procedure maintained urethral patency in only 4 of 14 cases in a California study.[5] Thus, if it is the only procedure performed, urethral process amputation may not result in a long-term cure.

Urethral catheterization and flushing

Retrograde urethral catheterization and saline flushing (termed urohydropulsion) is often successful in relieving urethral obstruction in cats and dogs. However, this procedure does not appear to be successful in most cases in small ruminants; only 1 of 35 small ruminants treated at admission with urohydropulsion became unblocked.[5] Retrograde catheterization of the ruminant bladder is very difficult because catheters tend to become lodged in the urethral recess (formerly termed urethral diverticulum), which lies on the dorsal aspect of the urethra at the level of the ischium.

Perineal Urethrostomy

Perineal urethrostomy is a popular surgical method for correction of obstructive urolithiasis in small ruminants. This procedure can be performed with sedation and local anesthesia, epidural anesthesia, or general anesthesia. It is a surgical option for ruminants not intended to be used for breeding. Its primary limitations involve stricture of the stoma and/or recurrent obstruction with additional calculi. These complications can occur within weeks to months after surgery. In four reports, half or more of small ruminants treated with perineal urethrostomy developed these complications in less than 12 months after surgery. [4-7] Therefore, this procedure may not be optimal for ruminants kept as pets.

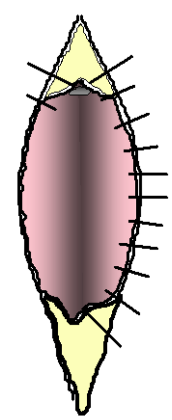
Urethrostomy can be performed at any site along the perineum, but the author prefers to place the urethrostomy site low in the perineum in order to minimize urine scalding of the skin and to allow room for repeated urethrostomy higher in the perineum if stricture at the original site occurs.

The skin and subcutaneous incisions are made on midline for a total length of 6-8 centimeters. Deep to the subcutis, the paired retractor penis muscles are found on midline. These muscles are superficial to the penis and easily separable into the two component muscles. These can be transected or simply retracted aside. The penis is relatively firm, 0.5-2 cm in diameter in small ruminants, and is covered by the white tunica albuginea. It may be located quite deep in the perineum in larger sheep, and as a rule, the higher (more dorsal) in the perineum that the approach is made, the deeper is the penis. While traction is placed to exteriorize the penile shaft, sharp and blunt dissection are used to free the penis from the surrounding fascia until a 4-6 cm segment of the penis can be exteriorized without tension. Adequate exteriorization of the penis is essential to minimize tension on the urethrostomy suture line.

If the surgeon elects to remove the penile segment distal to the urethrotomy site, ligation of the dorsal penile artery should be performed at a site on the penis 1-2 cm distal to a point that lies adjacent to the ventral apex of the skin incision. The cut end of the penile stump can be sutured closed to limit hemorrhage from the corpus cavernosum.

One or two simple interrupted sutures of 2-0 or 0 chromic catgut can be placed a small portion of the tunica albuginea of the penis and the subcutis of the distal apex of the skin incision to secure the penis in the desired position, with the ventral surface of the exteriorized penis located even with the skin surface The urethra is incised for 3-5 cm along the midline, and the urethral mucosa is sutured to the skin in order to provide a longer-lasting opening (stoma) for urine passage. Monofilament, 3-0 or 4-0, non-absorbable suture material is used to appose the mucosa to skin. A simple interrupted pattern or several small sections of a simple continuous pattern can be used. Intraoperative hemorrhage from the corpus spongiosum can be limited by digital pressure applied to the penis at the level of the ischium, or by placement of a catheter into the lumen of the proximal urethra to exert outward pressure on the corpus spongiosum. This catheter can be secured in place to limit postoperative hemorrhage. If not secured into the urethrostomy, the upper and lower aspects of the skin incision can be sutured closed. If urethral rupture exists, small stab incisions should be made through the skin and into the subcutis and abdominal musculature to facilitate urine drainage.

Fig. 3



Urethrotomy

The approach for urethrotomy is similar to that of the perineal urethrostomy, although an approach over the distal sigmoid flexure carries the best chance of being located directly over the calculus. Preoperatively, the calculi are located by palpation, ultrasonography, radiography, or by passage of a flexible catheter into the urethra. Local anesthetic is injected into the skin and subcutis over the site of obstruction. Some surgeons have been able to eliminate the obstructing calculus by crushing it through the urethral wall, using a towel clamp or other instrument. The calculus fragments are then passed or are milked out of the urethral opening. If the calculi are to be removed, the urethra is incised over the calculi, all calculi are removed, and the urethra is flushed in both directions to ensure patency. The urethral mucosa, subcutis, and skin are closed primarily. Simple interrupted sutures, using fine (3-0 or 4-0) monofilament absorbable suture material (e.g. PDS) are recommended for closure of the urethral mucosa. The skin is sutured separately.

Urtethrotomy is a poor choice for animals with urethral rupture because any attempt to close the urethra at the site of rupture is usually futile. Stricture of the urethrotomy site is a potential complication. In males, fibrosis at the surgical site could result in impairment of penile extension during erection, and development of cavernous fistulae may prevent erection.   A guarded prognosis for breeding is warranted if this technique is chosen.   A period of at least 60 days of postoperative sexual rest is recommended. Currently, no published data exists on the long-term outcome for this procedure in small ruminants.

Bladder Rupture: Is urethral surgery alone sufficient treatment?

If the urethral obstruction is successfully removed or bypassed, spontaneous healing of a bladder tear can occur, i.e. not all cases of bladder rupture require primary repair of the bladder wall defect(s). In many cases, the bladder defect(s) are apparently sealed by fibrin or by adhesions to the omentum. The location of the tear in the bladder is variable in ruminants. Tears on the dorsal aspect of the bladder are more likely to heal without surgical repair than are tears located on the ventral aspect. Until the bladder defect seals, repeated drainage of uroperitoneum may be necessary; the time to spontaneous closure of the bladder may be as long as one week. Close monitoring of hydration status and provision of electrolyte supplementation are warranted.

Cystotomy with Urethral Hydropulsion

General anesthesia is used most commonly, but lumbosacral epidural anesthesia may be suitable. The penis is exteriorized and secured with towel clamps to one side of the caudal abdomen. If present, the urethral process is amputated, and a 5-10 French polypropylene canine catheter is passed retrograde into the distal urethra. A paramedian approach is performed on the opposite side of the abdomen 1-2 centimeters lateral to the prepuce. It is important to place the incision caudal in the abdomen to allow for adequate exteriorization of the bladder.   To ensure adequate bladder exposure, the caudal aspect of the laparotomy incision should be located at the level of the rudimentary teats. Once the external sheath of the rectus abdominus is exposed, the surgeon may elect to enter the abdominal cavity either on the ventral midline (through the linea alba) or via a paramedian incision through the rectus abdominus and peritoneum.

Cystotomy is performed, and calculi are removed from the bladder lumen.   A 5-10 French polypropylene or rubber catheter is guided antegrade (also called normograde) from the bladder trigone into the proximal urethra. Sterile saline solution is flushed into the antegrade catheter to dislodge uroliths from the proximal urethra back into the bladder for removal.   Retrograde flushing is performed by an assistant (Figure 4). During retrograde flushing, the external urethral orifice should be squeezed shut with the fingers to prevent loss of saline from the urethral orifice. During retrograde flushing, the surgeon can place his or her finger in the pelvic urethra in order to occlude its lumen, which causes urethral distension and helps to dislodge urethral calculi. The urethra is considered free of calculi when

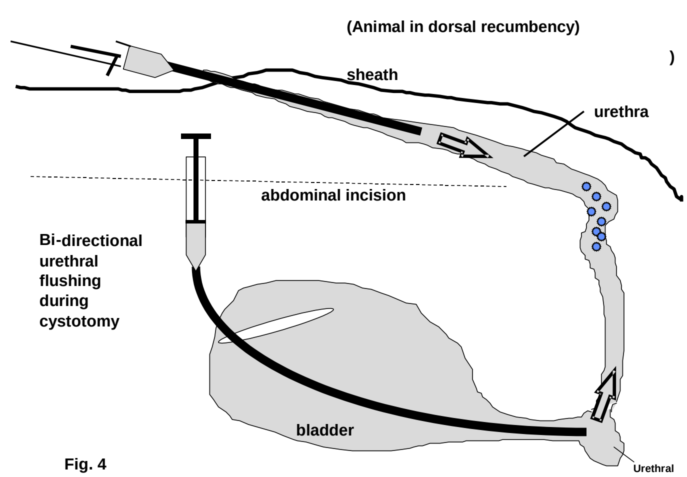


Fig. 4

saline can be easily flushed in the retrograde and antegrade directions. If rupture of the bladder has occurred, defects in the bladder wall should be sutured. The cystotomy incision is closed with two layers of absorbable suture in inverting patterns. The abdominal wall incision is closed routinely. Antibiotic therapy should be initiated prior to surgery and continued for 3-5 days.

Haven and colleagues successfully unblocked 7 of 8 small ruminants with this procedure; postoperative follow-up was limited.[4] In a California study, 8 of 11 small ruminants were successfully treated with cystotomy and urethral hydropulsion, but 5 of these animals experienced recurrent urethral obstruction at an average of 15 months after surgery.[7]

Disadvantages of this procedure include the potential for catheter-induced rupture of the urethra and the need for an assistant to perform retrograde urethral flushing. In addition, the duration of this procedure can be quite long (2-3 hours) if repetitive flushing is needed to dislodge large numbers of urethral calculi.

Tube Cystostomy

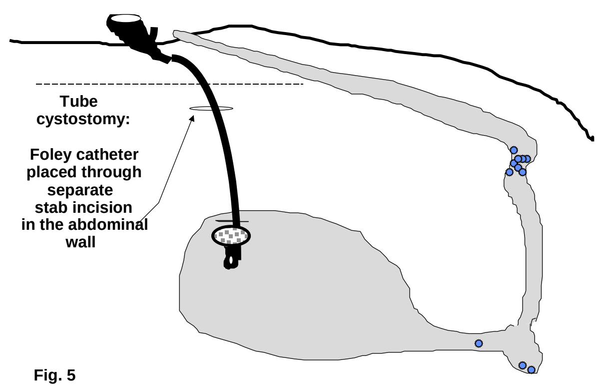


Fig. 5

General, lumbosacral epidural, or local anesthesia can be used. A paramedian approach or low flank (low and caudal in the paralumbar fossa) approach is used to enter the abdominal cavity and a small (1 cm) stab incision is made on the cranioventral aspect of the bladder. If available, lavage and suction are used to remove all bladder calculi. A stab incision is made in the abdominal wall 2 cm lateral to the paramedian incision; if a paralumbar approach is used, the stab incision is made 2-3 cm medial to the fold of the flank. An 8-20 french Foley catheter is passed through the stab incision and placed into the bladder lumen, as shown in Figure 5. The balloon end of the catheter is inflated, and drawn against the bladder wall. The stab incision in the bladder wall is reinforced with a purse-string suture of #0 vicryl of chromic catgut. The paramedian incision is closed routinely, and the Foley catheter is sutured to the skin at the stab incision and multiple other sites to protect it from being stepped on or pulled out (Figure 6).

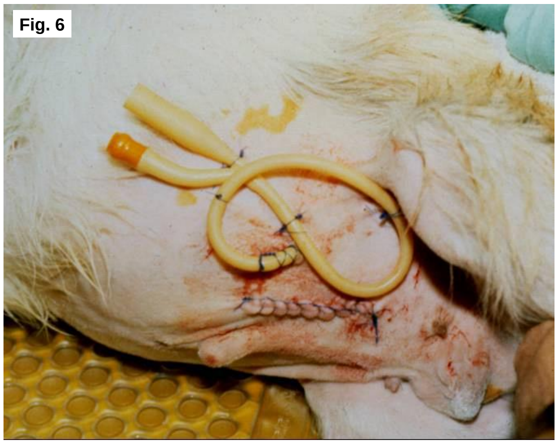


Fig. 6

Postoperatively, small ruminants should be fitted with an Elizabethan collar to prevent them from chewing on the catheter. Urine exits the bladder via the catheter, eliminating the pain associated with urine passage through an inflamed urethra. After 3-4 days, the catheter can be plugged or clamped shut to determine if the urethra has become patent. If signs of discomfort (vocalization, repetitive posturing to urinate, stranguria), are observed, the plug or tie should be removed and the animal allowed to drain its bladder via the Foley catheter. This process can be repeated daily. Apparently, in the days following surgery, controlled fluid pressure on the urethral calculi causes their eventual expulsion. Urethral patency is beginning to return when urine is seen to drip from the prepuce. In 15 small ruminants treated by tube cystostomy at Cornell University, urine first began to drip from the prepuce after an average of 7.5 days (range, 1-20 days) post-surgery.[2]

The duration that the catheter is plugged or clamped can be increased until the animal can void a steady stream of urine without discomfort. If normal urination takes place with the catheter occluded for 48 hours, the catheter can be removed by deflating the balloon and slowly pulling it out of the bladder and abdomen. The defect left in the bladder (the cystostomy site) is allowed to seal on its own. In one study, the catheter could be removed after an average period of 14 days post-surgery (range, 6-38 days).

Antibiotic treatment (penicillin, ampicillin, or sulfonamides) must be initiated prior to surgery and maintained until at least one week after catheter removal. Cystitis occurred in 2 of 15 small ruminants treated by tube cystostomy and should be considered to be a potential complication of this surgery.[2] Antibiotics and weak acid solutions, infused directly into the bladder via the Foley catheter, have been used to control cystitis and promote calculus dissolution, respectively.

Relative to cystotomy, tube cystostomy can be a less expensive procedure, primarily because general anesthesia is not always necessary. The duration of surgery is much shorter for tube cystostomy because repeated urethral flushing is not performed and a smaller incision in the bladder is made. Both procedures preserve breeding ability. Catheterization of the urethra, which carries the risk of iatrogenic urethral rupture, is avoided with tube cystostomy. Tube cystostomy is a valid treatment option if breeding ability is to be maintained in a ruminant with urethral rupture, as urethral flushing is ineffective in such cases.

Tube cystostomy can also be performed in animals with bladder rupture . The bladder defect can be surgically repaired, although in feeder lambs, the bladder tear may be left to heal on its own, and the animal salvaged for slaughter. Complications of tube cystostomy include ascending infection, recurrent obstruction of the urethra, and catheter obstruction, displacement, or loss.

This procedure successfully restored urethral patency in 12 of 15 small ruminants in a Cornell study.[2] Uroperitoneum, caused by leakage at the cystostomy site, developed in one animal whose catheter was removed relatively early, at day 6 after surgery.[2] Therefore, the catheter should be maintained for at least 7 to 10 days before removal to ensure that an adequate fibrinous or omental seal has developed. In another study, 8 of 10 small ruminants treated with tube cystostomy were successfully unblocked.[7] There was no statistically detectable difference in postoperative recurrence rates between tube cystostomy, cystotomy, and tube cystostomy with perineal urethrostomy, although the last procedure listed was associated with more rapid postoperative recurrence of obstruction than the other procedures.[7]

Bladder Marsupialization

This procedure involves creation of a permanent stoma between the bladder mucosa and the skin of the ventral abdomen, allowing for urine egress from the bladder to the exterior. It is a valid option as a primary corrective procedure for urolithiasis, as well as a salvage option for animals that have developed stricture of the urethra or a perineal urethrostomy. Postoperative urinary incontinence is inevitable, and urine scalding of the ventral abdomen may occur. Stricture of the marsupialization site and ascending urinary tract infection are potential complications of bladder marsupialization.

Local, epidural, or general anesthesia can be used. The animal is placed in dorsal recumbency and a 10-15 cm laparotomy incision is made 3 cm lateral to and parallel with the sheath. Urine should be aspirated from the bladder to facilitate bladder manipulation.

Two stay sutures are placed beside the apex of the bladder. A 3-4 cm, longitudinal cystotomy incision is made on the ventral aspect of the bladder apex. Copious lavage and suction are used to clear the bladder lumen of urine and calculi.

The apex of the bladder is then positioned against the peritoneal surface of the contralateral abdominal wall, equidistant from midline as for the laparotomy incision. The bladder apex is positioned as far cranially as possible without producing excessive tension on the bladder. This step allows the surgeon to determine the optimal location for the marsupialization incision. At this site, a second 4 cm paramedian, longitudinal celiotomy incision is made, which will be referred to as the marsupialization incision. The stay sutures are used to reposition the bladder apex through the marsupialization incision. The interior of the marsupialization incision is carefully inspected to ensure that bowel is not entrapped with the bladder apex.

Four simple interrupted sutures of absorbable, 0 or 00 monofilament material are placed through the external rectus sheath of the marsupialization incision and into the seromuscular layer of the bladder, immediately dorsal to the cystotomy incision, at the 12, 3, 6, and 9 o'clock positions. These sutures should be placed to position the edges of the cystotomy incision even with the level of the skin.

Next, the entire circumference of the seromuscular layer of the bladder immediately dorsal to (deep to) the cystotomy incision is sutured to the external sheath of the rectus abdmoninus, using 2-0 monofilament, absorbable material in an interrupted horizontal mattress pattern. The edges of the cystotomy incision are then sutured circumferentially to the skin, using 3-0 monofilament, absorbable material in a simple continuous pattern to appose the bladder mucosa to the skin. The abdomen is lavaged, and the laparotomy incision is closed routinely.

Postoperative antimicrobial therapy is continued for approximately one week. The hair on the abdomen may need to be clipped periodically to limit urine scald; nonetheless, urine scald is a consistent complication of this surgery.[8] The marsupialization site may require periodic cleaning. May and colleagues reported successful treatment of urolithiasis in 18 of 19 goats, with postoperative complications (infection and stricture) occurring in 2 goats. In the author's experience, owners tend to be concerned about the incontinence and urine scald inherent to this procedure. This appears to influence them to choose other procedures, even though owner satisfaction and animal comfort appeared to be quite satisfactory in the case series reported by May and colleagues.

Postoperative Care

Intravenous or oral fluid therapy should be continued for animals that are azotemic or remain inappetant. In the immediate postoperative period, fluid diuresis may help to prevent obstruction of the urethra (in cystotomy cases) or Foley catheter (in tube cystostomy cases) by clotted blood. In some cases, severe post-obstruction diuresis may occur, requiring aggressive intravenous fluid therapy to maintain hydration and electrolyte balance. Once the animal's appetite returns, salt should be gradually introduced into the ration, and appropriate dietary changes initiated. Non-steroidal anti-inflammatory drugs are administered for postoperative pain control, with due caution relative to hydration status and renal function.

Prevention

Regardless of the calculus type involved, dilution of calculogenic ions in the urine is of primary importance in prevention of urolithiasis in ruminants. The salt content of the diet should be gradually increased to promote water intake and formation of large volumes of dilute urine. In Canadian studies, loose or lick salt provided free choice proved inadequate for prevention of urolithiasis in animals at risk for silica calculosis. Thus, mixing the salt directly into the feed is the most effective means of delivery. Salt can be mixed in moistened feed or treats (e.g. corn chips with additional salt applied) or sprayed as a saturated solution directly onto hay. As a target quantity, s to feed, sodium chloride should be gradually added to the diet to a final level of 3-5% of daily dry matter intake. For an animal weighing 100 kg and ingesting 2% of its bodyweight in dry matter per day, this would translate to feeding 60-100 grams of sodium chloride daily.

Alternatively, ammonium chloride can be fed at a level of 0.5-1% of dry matter in the diet. At this level, ammonium chloride may induce modest reduction in urine pH (acidification), which may increase the solubility of magnesium ammonium phosphate (struvite), calcium carbonate, calcium phosphate, and silicate in the urine. This salt is unpalatable. For pet animals fed on an individual basis, molasses should be avoided as a flavoring additive for salted rations, as its high potassium content may diminish the acidifying effect of ammonium chloride. Table sugar works well for covering up the flavor of ammonium chloride. Long-term (months on end) feeding of ammonium chloride has been documented to reduce bone mineral content in mature ewes; this potential effect must be weighed against the desired effect on urolith dissolution.

It is important to impress upon owners the importance of encouraging increased water consumption in ruminants at risk for urolithiasis. It is crucial that a reliable source of water be readily accessible for ruminants on salt-supplemented diets. Canadian research determined that the dissolved mineral content, or hardness, of water is unlikely to play a significant role in bovine urolithiasis. Water containers should be cleaned and filled with fresh water on a regular basis. If automatic waterers are used, stagnation of water can be limited by using shallow tubs with spigots adjusted for rapid refill. Provision of shade over the water in the summer and heating the water during cold weather makes the water more attractive. For large groups of animals, provision of multiple watering sites allows for more frequent water intake. This is particularly important for sheep, as individuals are usually reluctant to separate from the flock to travel to distant watering sites. Finally, flavoring the water with sugar-free drink mixes has resulted in increased water intake in a limited number of cases in the author's practice.

Feeding frequency

Provision of a balanced ration in one or two feedings per day induces significant changes in body fluid homeostasis in ruminants. Meal feeding induces a surge in the production of ruminal volatile fatty acids, which exert an osmotic "pull" on the extracellular fluid (ECF). Water from the ECF is drawn into the rumen. Antidiuretic hormone is released in response to loss of free water from the ECF. A marked, albeit transient increase in urine concentration results, which promotes calculogenesis. These marked changes in urine concentration can be limited by frequent or ad libitum feeding.

Castration and age at castration

Several authors list castration, particularly castration at an early age, as a risk factor for development of urethral obstruction. Abattoir studies indicate that calculi form to a similar extent in the urinary tracts of bulls and steers. However, a bull may be able to pass a calculus that would likely obstruct the urethra of a steer. Owing to the trophic effect of testosterone, the urethral caliber (diameter) of yearling bulls was found to be approximately 25% greater than that of yearling steers.[9] The urethral diameter of unilateral castrates was intermediate to that of yearling bulls and steers. Urethral obstruction by calculi was a more common event in the steers of this study.

However, other factors may influence the trend for urolithiasis to be more common in castrates than intact males. First, there are more castrated male ruminants than male ruminants being fed calculus-promoting diets. Thus, there are more castrated males at risk. Second, males kept for breeding service are generally of greater individual value than castrated males, and better dietary and water management might place males at lower risk than castrated males.

Phosphatic calculi

Ruminants fed rations high in phosphorus, such as cereal grains, commonly develop struvite (magnesium ammonium phosphate) calculi. In 1965, Dr. Bushman proved that increases in dietary phosphorus levels generated increases in phosphate ion in the urine of lambs.[10] Because calcium opposes phosphorus absorption in the gut, phosphate absorption, and therefore the urinary phosphate load, are increased if the dietary calcium : phosphorus ratio is low (less than 1.5:1 calcium : phosphorus). Kallfelz and colleagues found that feeding calves diets high in magnesium with a normal (2:1) calcium : phosphorus ratio promoted calcium phosphate (apatite) calculogenesis.[11]

Ruminants fed pelleted rations may be at risk for development of struvite calculi. Ruminant saliva is rich in phosphorus, and the gastrointestinal tract is the primary route of phosphorus excretion in ruminants. In theory, ruminants fed pelleted rations produce smaller volumes of saliva, which would reduce gut phosphorus excretion and increase urinary phosphorus excretion. Maintenance of a total ration calcium to phosphorus ratio of 2:1 and a dietary magnesium level at or very near 0.2-0.3% (DM basis) will help to limit phosphatic urolithiasis.

Silica calculi

Silica urolithiasis is primarily a problem of sheep and cattle that graze native grasses of western North America. The silica content of these grasses tends to increase as the grasses mature, and can continue to increase even after growth ends. In some areas, 4-8% of total plant dry matter may be silicon compounds. Non-polymerized silicic acid in the rumen is absorbed into the bloodstream and excreted unchanged in the urine. During the periods of water deprivation, the kidneys of range ruminants perform avid water and sodium reabsorption, creating a highly concentrated urine. Concentrated silicic acid may polymerize, bind to urinary mucoproteins, and become insoluble under such conditions. Provision of multiple waterers, when possible, and multiple salt sources are the most common means of control for silica calculi in animals on range.

Calcium carbonate and calcium oxalate calculi

Most of the published information on calcium - based uroliths in ruminants comes from Australia, where the disease is seen most commonly in sheep grazing lush, rapidly-growing clover pastures. These forages are rich in calcium, low in phosphorus, and have a high oxalate content. In the gut, oxalate binds calcium avidly and makes it unavailable for absorption. With gradual adaptation to oxalate-containing diets, rumen bacteria efficiently metabolize oxalate to bicarbonate. Thus, microbial breakdown of oxalate in the rumen may increase the availability of dietary calcium. These factors combine to increase urinary calcium excretion and alkalinize urine, thereby promoting calcium carbonate calculogenesis. Owing to their calcium content, these calculi are usually radioopaque. They are usually present as multiple calculi rather than solitary stones.

Calcium carbonate uroliths have a characteristic dull gold color and resemble variably sized "BBs". In North America, calcium - based urolithiasis has been documented in small ruminants fed a diet of alfalfa hay.[7] Alfalfa and other legume hays contain far more calcium than a mature male or castrated male small ruminant needs for maintenance. As a result, urine calcium excretion can increase to the point of precipitation of calcium-based crystals. Adult male / castrated male small ruminants should be fed some type of grass hay as their primary forage source. Grass hay contains far less calcium than legume hay. However, occasional cases of calcium carbonate urolithiasis have occurred in small ruminants fed a low-calcium forage such as native grass hay, which brings to light the possibility of individual differences in calcium metabolism as a contributing factor. Hypercalciuria, both familial and idiopathic, has been incriminated in calcium-based urolithiasis in humans and dogs.

Given its very low solubility, calcium oxalate is often present as crystals in the sediment of concentrated ruminant urine. Oxalate is a normal end - product of glycine and ascorbic acid metabolism and is a constituent of normal urine. In man and dogs, inherent defects in calcium homeostasis and glycine metabolism contribute to calcium oxalate urolithiasis. Poisoning by oxalate - containing plants is not considered to be a common cause of this disease in ruminants. Measures aimed at reducing urinary calcium load, as for calcium carbonate uroliths, appear to be the most rational means of prevention of this urolith type in ruminants.

Summary

Surgical management of urolithiasis in small ruminants has been plagued by a high rate of postoperative recurrence of urethral obstruction. Owners of affected animals need to be well informed of this problem prior to surgery, and should be counseled to diligently institute preventive measures in order to maximize the chances of a recurrence-free life for their animals.

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