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KEYWORDS
- Ruminant urolithiasis • Veterinary urinary blockage • Urinary obstruction ruminants
- Urinary obstruction goat/sheep • Urolithiasis goat/sheep

KEY POINTS
- Urolithiasis is one of the most common emergencies in goats and, unless treated, is fatal.
- Amputation of the urethral process, with or without urine acidification, is usually unsuccessful.
- In the case of struvite stones, tube cystostomy gives the best results.
- In the case of calcium stones, survey radiographs are valuable to select an appropriate treatment plan.

RISK FACTORS AND UROLITH COMPOSITION

Several factors play a role in the development of urolithiasis, including anatomy of the urethra, age, sex, breed, water restriction, geographic location, and season. The urethra of the male ruminant is tortuous and narrow, thus facilitating lodging of uroliths at the sigmoid flexure, but more commonly in the urethral process of small ruminants.¹ Females are rarely affected, most likely because they have a shorter and wider urethra that facilitates passage of uroliths. Early neutering was suggested as a predisposing factor because it may result in underdevelopment of the urethra and decreased urethral lumen.² The first step for the development of urinary calculi is the presence of a nidus, usually formed by urinary tract debris, casts, mucoprotein, cells, or bacteria, followed by precipitation of minerals, which is favored by concentrated urine.³ In a study of uroliths from 832 goats, 44% contained more than 70% calcium carbonate, making this the most common type.⁴ Goats older than 1 year of age and breeds of African descent are at a greater risk of developing calcium carbonate uroliths than Anglo-Nubian, Nubian, and Toggenburg breeds.⁴ Nevertheless, other urolith types can affect very young small ruminants, putting every age category at risk. Geographic location and diet also have an effect on urolith composition. A study that evaluated 354 urinary calcium carbonate stones from goats revealed that 27% had been collected in the Midwest, 15% in the southeast, 11% in the Northeast, and only 4% from the

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Southwest. Calcium carbonate stones occur more commonly in animals fed forage or grass, calcium oxalate stones are associated with ingestion of oxalate-containing plants, struvite stones (magnesium ammonium phosphate) are associated with consumption of grain, and silica stones are more common in the Western United States and Canada where grasses have higher silica concentrations. Urine pH also plays an important role, since alkaline pH favors the development of calcium carbonate, struvite, and apatite stones.

CLINICAL SIGNS

Clinical signs vary depending on species, degree of obstruction, and duration of blockage. Small ruminants suffering from a complete blockage of the urethra often show severe signs of discomfort such as abnormal stance, straining to urinate, kicking at the abdomen, teeth grinding, vocalizing, and anorexia. Other signs may include pulsation of the urethra (visible in the perineum), tail swishing, teeth grinding, tachycardia, and tachypnea. A distended bladder can often be palpated in the caudal abdomen. Cattle, on the other hand, tend to show more subtle signs, such as anorexia and elevation of the base of the tail. Urolithiasis is common enough that it should be considered as a top differential in any male ruminant with colic. It is not unusual for goat and sheep owners to suspect constipation and gastrointestinal disease based on the clinical signs.

Animals suffering from a partial obstruction may experience more subtle signs, which are often accompanied by stranguria, polakiuria, and/or hematuria. The presence of edema around the prepuce or scrotum and in the caudal ventral abdomen are indicative of urethral rupture. Bladder rupture should be suspected if the animal seems to be depressed and the signs of pain dissipate, and when bilateral abdominal distention is observed. If unattended, obstructive urolithiasis causes severe uremia and death eventually.

The physical examination should include exteriorization of the penis, when possible. The following technique can be used to exteriorize the penis in small ruminants. The animal is restrained, with or without sedation, in a sitting position and 3 mL of a 2% lidocaine solution infused into the preputial opening. This maneuver desensitizes the prepuce and glans penis. The sigmoid flexure is pushed cranially, while the preputial skin is moved caudally. This maneuver exposes the preputial mucosa with the tip of the penis, which is firmly grabbed with a gauze sponge and pulled outward. Sedation may be required to exteriorize the penis and perform initial diagnostic tests. These authors prefer to use diazepam (0.1–0.3 mg/kg intravenously) as an anxiolytic and for urethral relaxation. Other commonly used sedatives are acepromazine (0.05–0.1 mg/kg, intravenously) or xylazine (0.05–0.1 mg/kg intravenously). However, both of these drugs may enhance hypotension and xylazine promotes diuresis; thus, their use is not recommended until the obstruction is relieved.

ANCILLARY DIAGNOSTIC TESTS

Time is important when dealing with cases of urolithiasis, because delaying treatment can lead to complications that can worsen the prognosis. Transabdominal ultrasonography, using a 3.5- or 5-MHz transducer, is a valuable tool to assess bladder size and the presence of free fluid in the abdomen, which indicates bladder rupture. This modality is also useful to evaluate the kidneys and to identify stones within the urinary system. The diameter of the bladder of affected goats usually ranges from 4 to 15 cm, depending on the animal’s breed and size. Regardless of size, a bladder that appears round with a thin wall should increase suspicion of urinary blockage. Bloodwork abnormalities are commonly associated with urolithiasis.
Assessment of blood urea nitrogen, creatinine, and electrolytes are valuable to support the diagnosis, determine chronicity, establish prognosis, and aid in implementation of supportive care to stabilize metabolic derangements. Abnormalities include hemoconcentration, azotemia, hyponatremia, and hyperkalemia. These changes are most likely associated with reduced glomerular filtration rate and compromised renal tubular reabsorption and tubular secretion. Other abnormalities may include hypochloremia, hypocalcemia, and hyperphosphatemia. Nevertheless, these changes are not always present early on, because ruminants seem to benefit from salivary secretions to better manage uremia, hyperphosphatemia, and hyperkalemia.6

Plain radiographs are sometimes performed in an attempt to determine the location of the blockage, the number of stones, and the radiolucency of the stones, which can be useful in determining the prognosis, and establishing the treatment and postoperative management. The disadvantage of obtaining radiographs on admission include time, cost, and the fact that only radiopaque calculi (calcium carbonate, calcium oxalate, silicate, etc) can be visualized. Therefore, radiographs are usually recommended in cases where radiopaque stones are suspected based on geographic region7 or diet. It is recommended to obtain 2 lateromedial projections, one with both pelvic limbs pulled cranially (toward the elbows) and one with both pelvic limbs pulled caudally to allow visualization of the urethra and bladder without superposition of the bones of the pelvic limbs.7

INITIAL CARE

The ultimate goal is to allow urine excretion, which in most cases can only be achieved with surgical treatment. In some instances, amputation of the urethral process (vermiform appendage) at the connection with the glans may resolve the obstruction, followed by treatment with orally administered ammonium chloride to acidify the urine in an attempt to dissolve struvite stones. Ammonium chloride, 450 mg/kg every 24 hours, was successful at lowering the urine pH to less than 6.5.8 The authors prefer to check urine pH daily and use ammonium chloride to effect because it is unpalatable, often having a negative effect on appetite, and it can cause metabolic acidosis if used extensively. Unfortunately, the rate of reoccurrence is high in cases treated medically because ruminants typically develop several small stones rather than a single urolith, making it likely that another stone will get lodged in the urethra before urolith dissolution can be achieved with urine acidification.

A soft urinary catheter can be inserted in the urethra in an attempt to localize the blockage; however, the presence of the urethral diverticulum at the level of the ischial arch hinders passage of a catheter into the bladder.9 Retrograde hydropulsion is not recommended because it is often unsuccessful and could exacerbate damage to the urethra.

Hyperkalemia should be addressed, especially if greater than 6 mmol/L, to decrease the risk of fatal cardiac arrhythmias. Therapy with insulin and dextrose can be implemented to favor shifting of potassium intracellularly. Calcium gluconate decreases the risk of arrhythmias by increasing the threshold potential, but its effect is temporary. Fluid therapy is indicated after resolution of the obstruction to address dehydration, restore kidney function, and flush the urinary system. Normal saline (0.9%) is usually recommended because hypochloremia and hyponatremia are common in these patients; however, treatment should be based on electrolyte status. Nonsteroidal antiinflammatory drugs can be useful to decrease inflammation of the urethra and prevent formation of strictures, but should be used with caution until renal perfusion is reestablished. Their use is discouraged in cases with severe azotemia to prevent further
damage to the kidneys. Antimicrobials may be used off label to prevent infections associated with a compromised urinary system and/or surgical treatment.

TREATMENT

Urolithiasis is often a difficult and challenging problem. Cost and other factors that may influence a successful outcome are important to consider. Chronic obstruction may cause bladder rupture or atony, which often result in azotemia and electrolyte changes and backing up of urine, thus predisposing to hydronephrosis. It is also important to look for signs of urethral rupture, such as perineal and/or ventral swelling because that may dictate the best treatment option, which would include urine diversion techniques as the primary treatment approach or perhaps culling in case of breeding animals.

The primary food and water source could also be used as basis for developing a treatment plan. Struvite (magnesium ammonium phosphate) is often reversible in an acidic solution, whereas calcium stones, such as calcium carbonate or phosphate (apatite), are more stable and less likely to dissolve. If struvite is likely to be the cause of the obstruction, treatment options include cystocentesis and bladder irrigation with an acidic solution, or tube cystostomy placed percutaneously, laparoscopically, or via laparotomy, and normograde hydropulsion followed by irrigation with an acidic solution. Fig. 1 presents a flow chart of possible treatment alternatives after tube cystostomy. If calcium stones (calcium carbonate or phosphate–apatite) are suspected as the primary cause of the obstruction, survey radiographs are useful to determine a treatment plan, because the urethra may be obstructed with a large number of stones (pearl string effect) (Fig. 2). In such cases, better results may be obtained if another primary surgical approach such as perineal urethrostomy, bladder marsupialization, urethroscopy, and laser lithotripsy and vesicourethral anastomosis (UTVCM, unpublished data) is used. In the case of calcium stones, survey radiographs may aid in selection of the best treatment plan based on number and anatomic location of stones (Fig. 3).

Amputation of the urethral process in small ruminants, with or without urine acidification, usually precedes these treatment options, but is typically only effective in

Fig. 1. Treatment plan for obstruction caused by struvite stones. a 76% success rate; urination, 11 days; hospitalization, 14 days; <20% reobstruction. b Perineal urethrostomy, marsupialization, long term foley, vesico-preputial anastomosis.
about 50% of cases, and the recurrence rate is 80% to 90% within hours or days. Nevertheless, amputation of the urethral process should always be part of any treatment strategy because stones are often lodged there (Fig. 4). In some instances, the glans penis may show signs of necrosis, which may lead to stricture. The penis

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**Fig. 2.** Urethra obstructed with a large number of stones.

**Fig. 3.** Treatment plan for obstruction caused by calcium stones.
should be exteriorized as previously explained, and the urethral process can then be removed obliquely with a pair of scissors. In animals with an intact frenulum, the urethral process is peeled away from the tip of the penis before amputation.\textsuperscript{11}

**Cystocentesis and Bladder Irrigation with an Acidic Solution**

If obstruction is suspected to be caused by struvite stones, cystocentesis and bladder irrigation with an acidic solution, such as Walpole’s solution, is an option.\textsuperscript{10} This procedure was carried out in 25 concentrate-fed goats with a median age of 9 months. The goats were placed in left or right lateral recumbency, and an ultrasound-guided cystocentesis was performed using a 1.5- to 3.5-inch, 18-gauge needle to which a 30-inch extension set was attached, and urine was aspirated using a 60-mL syringe. To ensure that the needle remains within the bladder, the tip should be visible on ultrasound at all times. A volume of 120 to 500 mL of urine is removed and the pH determined. Fifty milliliters of Walpole’s solution (pH 4.5 and composed of sodium acetate [1.16\%], glacial acetic acid [1.09\%], and distilled water [97.75\%]) is infused into the bladder and, after waiting about 2 minutes, a second urine sample is obtained and the pH measured. Decompression of the bladder and administration of Walpole’s solution is repeated until a urine pH of 4 to 5 is achieved. The cystocentesis needle is left in place during the procedure.\textsuperscript{10} The urethral obstruction initially resolved in 20 of the 25 goats with this treatment; however, obstruction recurred in 6 of the 20, and only 9 of 13 goats in which long-term follow-up information was available returned to their intended use.\textsuperscript{10}

**TUBE CYSTOSTOMY**

**Percutaneous**

Percutaneous tube cystostomy is primarily used as a cost-saving procedure, because it usually eliminates the need for general anesthesia, or it can be performed in situations where general anesthesia is not available, or as a time-saving procedure compared with other surgical interventions.\textsuperscript{11,16–19} However, the incidence of complications is high.\textsuperscript{15} The procedure was carried out, as follows, in 12, 4 to 8-month-old male goats in which overdistention of the bladder was confirmed on abdominal palpation. With the animal in right lateral recumbency, a 1-cm incision was made through the skin 3 to 4 cm left lateral to the penis and 3 to 4 cm cranial to the scrotum. The abdominal cavity was penetrated using blunt dissection. A subcutaneous tunnel was created using a straight hemostat, and a Foley catheter was pulled through the tunnel. A 5-mm Kirschner wire was inserted into the Foley until it penetrated through

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*Fig. 4. Stone lodge in the urethral process.*
the end. The Foley with the wire was then pushed through the abdominal opening until it was felt to be up against the bladder wall. The wire with the Foley was then pushed through the bladder wall using a sudden thrust, and the cuff inflated using 5 mL of saline. The Foley catheter was anchored to the skin. Follow-up treatment included ammonium chloride given orally. All the animals started urinating after 5 to 9 days, and the catheters were removed after 12 to 15 days. In another approach, the animal remains standing and after an anesthetic line block in the caudal left flank, a 2-cm vertical incision is made into the abdomen. Using an index finger, a catheter attached to a cannula, such as a teat cannula of which the tip had been sharpened, is guided into the abdomen. The cannula is moved ventrally to the dorsal surface of the bladder, at which point it is thrust into the bladder. Urine flow should start immediately, after which the cannula is moved deeper into the bladder. The catheter is fixed to the skin on the outside. This technique was used on 7 goat kids and 3 lambs. Surgical time ranged from 9.7 to 18 minutes. Urine flow stopped in 2 goat kids after 3 to 4 days and this was due to kinking and collapse of the tubing. The mean time to normal urine flow was 7 days for the remaining 8 animals.

Another study found that percutaneous tube cystostomy resulted in a reduced time to, and an increased requirement for, a second surgical intervention. Failure resulted from tube displacement from the bladder, persistent obstructive urolithiasis, recurrence of obstructive urolithiasis, and urethral rupture. In that study, 8 goats in which the percutaneous tube cystostomy failed subsequently underwent a second procedure, and had adhesions between loops of the small intestine, and between the small intestine and bladder. This may have been due to leakage around the tube or the type of catheter used.

**Laparoscopic**

Laparoscopic-assisted cystotomy has been described in 5 normal male sheep. With the sheep in dorsal recumbency, a right paramedian 1.5-cm stab incision was made into the abdomen caudal to the umbilicus which allowed the insertion of a 10-mm trocar–cannula system. The abdomen was insufflated with CO₂ to an intraabdominal pressure of 13 mm Hg. The surgical table was tilted to a 20° head-down position to displace the abdominal viscera cranially until the bladder could be visualized. A second paramedian portal was made on the left side close to the teats. Using a 5-mm trocar–cannula system, a forceps was inserted through the portal and the bladder grasped at its apex and elevated to the inside of the body wall. A 3-cm incision was made in the inguinal area overlying the elevated bladder, which was pulled to the outside during desufflation of the abdomen. After placement of stay sutures, a cystotomy was performed and the bladder lavaged. After suturing the cystotomy site, the bladder was replaced in the abdomen. The sheep were repositioned in a head-down position and the abdomen reinflated. The bladder is again grasped with the forceps and a pigtail-tip balloon is inserted through a cannula. The balloon is inflated and the catheter fixed to the skin on the outside. There were no postoperative complications.

**Laparotomy**

The most successful surgical method for treating obstructive urolithiasis in cattle and small ruminants is surgical tube cystostomy. Cystotomy allows removal of stones from the bladder and urethral flushing. Tube cystostomy establishes urinary diversion and facilitates reestablishment of urethral patency. This procedure has been carried out in sheep, goats, cattle, camelids, and buffalo. With the animal in dorsal recumbency, a paramedian incision is made immediately proximal to the pubis. The bladder is usually covered by omentum, except in camelids, and may contain a lot of fat, making it more difficult to visualize. Two stay sutures, which are
used to exteriorize the bladder, are placed near the apex. A cystotomy is performed on
the ventral surface, and suction of the urine removes the majority of the stones. The
bladder trigone is palpated for additional stones. Normograde flushing is performed us-
ing a suitably size polypropylene catheter. With a finger deep in the trigone to prevent
back flushing, saline is flushed through the catheter with gentle pressure in an effort to
dislodge and remove any additional stones from the urethra. Normograde flushing is
more likely to be successful in the case of struvite stones. Calcium stones are generally
larger and tend to cause multiple blockages along the distal urethra, which makes nor-
mograde flushing ineffective. The cystotomy site is closed using a double inverting
pattern. A purse string suture is placed away from the cystotomy site near the apex of
the bladder. An 8-inch, 22-gauge Foley (female) catheter is pulled through a stab incision
in the abdominal wall lateral and opposite to the caudal part of the abdominal incision.
The Foley catheter is then inserted into the bladder through a stab incision in the center
of the previously placed purse string suture, which is then tied. After inflation of the
balloon, the bladder is pulled up against the abdominal wall and secured on the outside.

The abdominal incision is closed. The bladder is flushed with saline to verify that
there is no obstruction of flow through the Foley catheter. Overinflation of the catheter
may result in discomfort and straining. By creating a diversion for urine flow through
the catheter, inflammation in the urethra should subside over a few days postopera-
tively and facilitate passage of more stones; in some cases, the animal will start normal
urination. If no urine has been observed to pass through the penis by 5 days postop-
eratively, the catheter can be clamped for up to 5 hours. However, if the animal
shows discomfort and straining without passing urine, the Foley catheter should be
unclamped. Instillation of an acidic solution such as Walpole’s or hemiacidrin
(Renacidin) may aid in dissolving residual stones. The authors would typically start
infusing 30 mL of the solution, after which the Foley catheter is clamped for 30 minutes
unless the animal is showing undue discomfort. More of the solution can be infused for
longer periods of time during the following days. Once a good stream of urine is pre-
sent, the clamp can be left in place for 24 hours and the animal observed for normal
urination, at which time the Foley catheter can be removed.

In 2 separate reports, urine flow was reestablished in a mean of 11 and 11.5 days. If the animal is not able to urinate after 3 weeks, surgery to establish permanent urinary
diversion has to be considered. The success rate for tube cystotomies is more than
80% for sheep, but lower for goats because of the high incidence of calcium carbon-
ate stones. Other reports indicated success rates of 76% to 90% in the short term
and 86% in the long term. Rarely, the tube becomes dislodged and lost, and if this
happens shortly after the initial placement, insertion of another tube may be difficult
because of the absence of a walled off track between the bladder and abdominal
wall. One of the major problems with surgical tube cystostomy is the cost associated
with prolonged hospitalization. For this reason, the authors recommend radiographs
on presentation if calcium stones are suspected, because in these cases multiple
stones are commonly present in the urethra (pearl string obstruction), and a tube cys-
tostomy often does not resolve the obstruction.

Tube cystostomies have been used in other species including, old and new world
camelids, potbellied pigs (van Amstel, unpublished data, 2014), cattle, and buffalo. Complications after tube cystostomy in camelids (n = 18) included an inability to
restore a patent urethra (n = 5), development of uroperitoneum upon removal of the
cystostomy catheter (n = 1), removal of the tube by the animal (n = 1), and develop-
ment of testicular swelling (n = 1). In 35 buffalo calves and 23 goats with obstructive
urolithiasis treated with tube cystostomies, 80% of the calves and 86% of the
goats made an uneventful recovery. Normal urination through the urethra returned
12 to 18 days postoperatively. Complications included urethral rupture in 5 calves and obstruction of the tube in 2 calves and 2 goats. In 125 cases of urolithiasis (33% goats and 66% buffalo calves), follow-up on 88% of these cases reported catheter obstruction in 12% of animals and urethral rupture in 6%. Catheters were removed between 13 to 17 days, except in 12% of cases (all buffalo calves) in which catheters were remove after 1 month.

Long-term tube cystostomy can be used when other techniques, such as stricture after perineal urethrostomy, have failed. The advantage of this technique is that the incidence of urine scald is less than with bladder marsupialization. The main problems associated with this approach is catheter loss or blockage with cellular debris or new stone formation. To prevent this, an 8-inch 22 F-gauge (female) catheter is used, and this should be replaced every 4 to 6 weeks. The catheter should be replaced as soon as possible after loss because of rapid narrowing of the tract into the bladder.

**Bladder Marsupialization**

Urinary bladder marsupialization may be an option where other surgical interventions have failed or when owners are not willing to accept the risk of reobstruction associated with other procedures. Advantages include simplicity of the technique, and decreased hospitalization time and duration of treatment. Although the success rate is relatively high (80%), all animals are affected by urine scald. Other complications include bladder mucosa prolapse through the stoma and ascending infections. Marsupialization is performed with the animal in dorsal recumbency. A 10-cm incision is made in the caudoventral abdomen approximately 3 cm lateral and parallel to the prepuce. The apex of the bladder is identified and exteriorized using gentle traction. A stay suture is placed at each end of the intended cystostomy, which is about 4 cm in length. A second 4-cm paramedian incision is made on the contralateral side from the prepuce. This incision is placed as far cranial as possible to limit urine scalding without creating excessive tension on the bladder. With the aid of the stay sutures, the apex of the bladder is positioned through the second abdominal incision, taking care not to trap any small bowel. The most cranial, caudal, medial, and lateral aspects of the incision in the bladder is anchored to the abdominal wall. The serosa and muscular layers of the bladder is sutured circumferentially to the peritoneum and muscle of the abdominal incision. The mucosa of the bladder is then sutured to the skin in a simple interrupted pattern to ensure good mucosa-to-skin apposition. In a study that included 19 goats, short-term postoperative complications included bladder mucosal prolapse and death in 2 goats. Long-term complications included cystitis and fibrotic stomal closure occurred in another 2 goats. Urine scald was reported in all surviving animals.

Seven normal 3- to 6-month-old goats were used in a study to evaluate the outcome of bladder marsupialization. Four goats survived to day 180. One goat was found dead at day 150 and had suppurative fibrinonecrotic cystitis with occlusion of the stoma. Another goat developed complete stomal stricture by day 120. The severity of the urine scald seemed to be directly related to the size of the stoma. Animals with larger stoma had a larger area of scald, and vice versa. The mean stomal diameter was 2.25 cm immediately after surgery, and this decreased at a rate of 0.24 cm per month thereafter, and the mean stomal size was 0.53 cm by day 180. Clinical signs related to ascending infections were not observed in the 5 remaining goats. Necropsy showed a tubular-shaped bladder, but all urinary tract organs were grossly normal. Histologic examination of the skin showed a superficial, proliferative perivascular dermatitis with chronic lymphoplasmacytic infiltration.
PREPUBIC URETHROSTOMY

Prepubic urethrostomy is a surgical option to correct urine outflow obstruction after stricture formation associated with perineal urethrostomy in small ruminants. The surgical procedure was carried out in a sheep as follows. The previous urethrostomy site was freed by means of a circumferential incision, and the penis amputated distal to the strictured area. After a caudoventral midline incision, muscles from the medial aspect of the upper leg were cut and reflected from the pubis and ischium, and the prepubic tendon was transected. Bilateral pubic and ischiatic osteotomies were carried out and the pubis removed to expose the pelvic canal. The perineal incision was closed and the pubis replaced and secured with stainless steel wire through predrilled holes. The prepubic tendon was sutured to the pubis through predrilled holes. The intrapelvic portion of the urethra was freed by means of blunt dissection and moved down to the caudal part of the abdominal incision. To prevent mechanical obstruction to urine flow, an angle of greater than 50° between the urethra and bladder should be maintained. The urethralis muscle is used to secure the urethra to the abdominal wall. The abdominal wall is closed, taking care not to make it tight around the urethra. The urethral mucosa is spatulated for about 1 cm and then sutured to the skin, making sure that good apposition is achieved, because this limits granulation and scar tissue formation. Other complications included incisional hernia presumably caused by sectioning of the prepubic tendon during the initial surgical procedure. In that case, the sheep died 3 years after surgery, and pyelonephritis was suspected as the cause of death. In another case, prepubic urethrostomy was carried out in a 2-year-old Pygmy goat, but osteotomies were not performed. The goat developed stricture at the urethral orifice 2 months after the surgery and was euthanized. It was concluded that pubic osteotomy may not be needed in small ruminants because the intrapelvic urethra is long enough to be transposed without causing too much tension. In another case, prepubic urethrostomy was carried out after stricture of a previous perineal urethrostomy. It was described as a very invasive procedure that leaves a lot of dead space, and an intrapelvic abscess developed. The same case also developed severe urine scald (Van Amstel et al, unpublished data).

PERINEAL URETHROSTOMY

Perineal urethrostomy is a well-documented technique for the treatment of urolithiasis in cattle and small ruminants. A permanent opening is made in the urethra, and the anatomic location of the opening varies from “high” perineal urethrostomy located near the ischium to “low” located above the scrotum. These are regarded as salvage procedures because the incidence of stricture formation may be 45% to 78% within 8 months. Low urethrostomies were reported in 7 Belgian Blue bulls. Three cases were regarded as successful, and were slaughtered 5 months after surgery. Two animals showed insufficient weight gain and were slaughtered 1 to 2 months after surgery. One animal died after 3 months of unknown causes, and another obstructed again. A modified proximal perineal urethrostomy uses the intrapelvic urethra because of its greater diameter as compared with the extrapelvic part. For this procedure, a 6- to 8-cm vertical incision is made from just above the ischium. The penile body is located through blunt and sharp dissection and freed from surrounding soft tissue to the level of the ischium. Dissection between the penile body and dorsal penile vessels is carried out before transecting the penis 1 to 1.5 cm below the ischium. For identification and orientation during the procedure, a catheter is placed in the urethra. Blunt dissection is continued to identify the retractor penis muscle, if present, and the ischiocavernosus muscle attachment to the penis. These are carefully transected, making sure not to
cut into the penile body or urethra. Continue to separate any further attachments from the urethra until it is possible to slide a finger around the intrapelvic urethra. For this purpose, the tunica albuginea can be grasped. The area is vascular and a fair amount of hemorrhage can be expected. Next the urethra is opened, making sure that the incision remains centered and continued to just dorsal to the ischium. Using 3-0 monofilament absorbable suture and starting at the top of the incision, the urethral mucosa is sutured to the skin on either side to create a funnel. Sutures should be placed so as to create good skin to mucosa apposition. Any remaining skin wounds are closed. In the study reported here, hemorrhage was the most common complication intraoperatively and postoperatively. Other complications included misdirected urine stream, obstructive urolithiasis, bladder atony, dysuria, dehiscence, delayed healing, renal failure and persistent cystitis. Urethrostomy sites were patent and functional in 9 goats available for follow-up beyond 12 months.

Mucosal grafts for reversal of stricture after perineal urethrostomy are not commonly performed but one report describes a successful outcome after buccal mucosal graft urethroplasty in a goat wether.

PRESCROTAL URETHROTOMY

Prescrotal urethrotomy was reported in 25 calves suffering from obstructive urolithiasis affecting the sigmoid flexure. The surgical procedure was carried out by making a 5-cm prescrotal incision lateral to the penis. The sigmoid flexure was freed using blunt dissection. The penis was ligated proximal and distal to the obstruction followed by a urethrotomy over the area of obstruction. The proximal ligating suture was removed and a flexible Rayle’s catheter was passed from the urethrotomy site into the bladder to make sure no other stones were present in the proximal urethra. The catheter was removed and the urethrotomy site closed. The Rayles catheter armed with a flexible wire was then passed retrograde up the urethra into the bladder and sutured to the glans penis after removal of the wire guide. The tube was removed after 8 to 10 days. Complications developed in 4 animals including infection at the surgical site in 2 calves; another developed adhesions at the sigmoid curve with phimosis as a consequence, and another calf developed a ruptured urethra. The rest of the calves retained their normal erection and breeding capability.

Urethroscopy and Laser Lithotripsy

Urethroscopy and laser lithotripsy can be used successfully where urethral obstruction is caused by a small number of hard stones such as calcium carbonate or phosphate (Bartges, unpublished data, 2013).

Vesicopreputial Anastomosis

This is a novel unreported technique (Department of Large Animal Clinical Sciences, College of Veterinary Medicine, University of Tennessee) to redirect urine flow after failure to reestablish urination after techniques such as tube cystostomy or perineal urethrostomy. This technique is carried out as follows. With the animal in dorsal recumbency, a rigid probe is inserted through the preputial opening to the end of the preputial sac. With this landmark as a guide, a 6- to 8-cm incision is made 1 cm lateral and parallel to the preputial skin so that the middle of the incision is in line with the end of the preputial sac. The abdominal cavity is opened and the urinary bladder located and 2 stay sutures placed through the apex without entering the lumen. The bladder is pulled through the abdominal incision for about 3 cm. The bladder wall is then sutured to the abdominal wall in such a manner so as to form a tight seal. Next, the caudal end of the preputial sac and penis are
freed from the skin and abdominal wall. A circumferential incision is made into the prepuce where the penis enters the preputial cavity. A prescrotal penile amputation (penectomy) is performed and the cranial transected portion of the penis removed. The opening in the prepuce is enlarged to where it can easily accommodate a 22-F gauge Foley catheter. Next, a similar size opening is made in the apex of the bladder. A 2-layer anastomosis between the preputial sac and the bladder is then performed making sure that good apposition between bladder and preputial mucosa is attained. An 8-inch 22-gauge Foley catheter is placed through the preputial opening into the bladder and the balloon inflated (Fig. 5). The Foley catheter is left in place for 3 to 4 weeks until healing has occurred. This technique can be used as a replacement for bladder marsupialization because urine scalding does not occur. Of the 4 cases performed using this technique, 1 goat died of hydronephrosis after stricture, 2 goats are doing well on follow-up 6 months after surgery, and the remaining goat had a second anastomosis performed after the first strictured.

**Penile Amputation**

Penile amputation is similar as described for perineal urethrostomy. In this technique the penis is transected in the perineal area (high or low) rather than creating a stoma. The distal part of the penis is left in place and not removed unless necrotic. This is a salvage procedure and is commonly done in cattle feedlots.

**REFERENCES**