Diagnosis and management of obstructive urolithiasis in miniature pigs

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This article provides information to assist practitioners in the diagnosis, medical, and surgical management of obstructive urolithiasis in miniature pigs. The article focuses primarily on pigs managed as pets because production swine rarely undergo intensive treatment for urolithiasis. As much as possible, the information in this article is based on published literature, but given the limited number of publications addressing obstructive urolithiasis in pigs, some information is based on the authors’ clinical experience. Medical and surgical management of obstructive urolithiasis of pigs is often similar to management in ruminant and small animal species, but differences in swine anatomy, handling, and temperament create unique challenges. Pigs tend to be more difficult to restrain and examine than other livestock and often require heavy sedation or anesthesia to facilitate physical examination and basic diagnostic procedures. Because pigs are monogastrics, some oral treatments used in small animals may be used effectively in pigs. Clinicians should follow AMDUCA and consult the Food Animal Residue Avoidance Databank prior to extralabel drug use because pet pigs are still considered a major food-producing species in the United States.

With the increasing popularity of pet pigs, veterinarians are frequently asked to evaluate and treat miniature pigs. While many pet pigs are “miniature” pigs or Vietnamese potbellied pigs, occasionally commercial or heritage swine breeds are kept as pets or are obtained by rescue organizations. In addition to providing basic veterinary care for these patients, practitioners are faced with treating medical and surgical conditions that did not historically arise in the swine population or were not treated when the animals were raised to enter the food chain. Obstructive urolithiasis in pigs is challenging to effectively diagnose and treat. This article provides an overview of diagnostic and treatment considerations to help veterinarians manage obstructive urolithiasis in pigs.

Signalment, History, and Clinical Signs

The typical pet pig patient presenting for suspected urinary obstruction is a young adult barrow (castrated male). In potbellied pigs, males, and particularly barrows, are most often affected.1 However, females can also develop clinical signs of urolithiasis.1-2 Age at admission to a referral hospital for obstructive urolithiasis and surgical tube cystostomy was reported in 6 pet barrows and ranged from 3 months to 12 years (median of 4 years).3 Weight ranged from 1.7 to 350 kg (median of 44.7 kg).3 Young age, small size, or low bodyweight should not preclude the clinician from considering obstructive urolithiasis as a differential diagnosis in pet swine. Clinical signs of obstructive urolithiasis in pigs may be less obviously referable to the urinary tract compared with ruminant species. Clinical manifestations of urinary obstruction may be incorrectly interpreted as constipation or other gastrointestinal (GI) dysfunction by owners. Commonly reported clinical signs are often nonspecific and include lethargy, depression, and hypo- to anorexia. Tail flagging/writhing, tenesmus, intermittent recumbency (generally interpreted as colic or discomfort), stranguria or dysuria with or without urine dribbling, pollakiuria, or hematuria may be noted during the exam or these findings may be elicited by taking a detailed history. Many indoor pigs use a litter box or are escorted outside to urinate and defecate, so specific questions regarding voiding habits can be useful because urination is often witnessed by the client. Dysuria and pollakiuria have been reported in a female potbellied pig with clinical urolithiasis.2 The authors have evaluated pigs for a history of vomiting or generalized lethargy and “ADR” (“ain’t doing right”) that were subsequently diagnosed with rupture of the urinary bladder.

A thorough physical examination is important in any case of suspected urinary obstruction in pet pigs. Complete physical examination of pigs, even
pet pigs, can be challenging to perform and may be facilitated by use of belly rubs, small treats, mild sedation with diazepam or midazolam, or “forking,” which is gentle pressure with a fork or other blunt tip object repeatedly over their back and sides. There are commercially available "forks" made and marketed specifically for this purpose although a regular plastic fork appears to work in many cases. Pigs that may undergo general anesthesia for diagnostics and/or treatment should ideally not receive treats or multiple rounds of sedation prior to induction to avoid vomiting and prolonged anesthetic recovery, respectively. It is notable that owners of pet pigs often expect them to be handled and treated in a manner similar to small animals. Normal physical exam parameters for adult miniature pigs are as follows: temperature, 37.6 to 39 °C (99.7 to 102.2 °F); heart rate, 70 to 80 beats/min; and respiratory rate, 12 to 15 breaths/min. Abnormal physical exam findings in cases of urinary obstruction in pigs may include tachypnea and increased rectal temperature, as well as urethral pulsation, straining, and pain on abdominal palpation. Digital rectal exam is useful for determining if urethral pulsations are present and, in the absence of concurrent normal urine production, is indicative of urinary obstruction. Digital rectal exam is also helpful in determining if feces are present and of normal consistency and appearance; this may be facilitated by use of lidocaine gel or sedation. Palpation of the prepuce and penis transcutaneously is encouraged but may not be tolerated. Peripreputial or peripenile edema can be indicative of a urethral rupture with subcutaneous urine accumulation. In obese animals, palpation of the penis is often extremely challenging even in sedated or anesthetized patients. Attempting to ballot a fluid wave and performing deep abdominal palpation to determine if there is an enlarged urinary bladder or discomfort indicative of abdominal pain can also provide useful information. However, this may be quite difficult to perform effectively in fractious or overweight pigs.

## Diagnostic Tools

### Ultrasonography

Ultrasonography of the urinary tract and abdomen can be an extremely useful tool in cases of suspected obstructive urolithiasis in pet pigs (Table 1). This can often be performed in an awake, compliant animal, so it is often the first diagnostic test performed after the physical exam, although fractious animals may require sedation or anesthesia. Handheld point-of-care ultrasound units are ideal for this purpose. Ultrasonography of the urinary bladder, kidneys, ureters, and urethra can help evaluate for urethral or ureteral dilatation or presence of uroliths, pyelectasia, or hydronephrosis. Normal urinary bladder size has not been reported in pigs to the authors' knowledge. Larger patients would be expected to have a larger urinary bladder diameter than smaller patients, and evaluation of shape rather than diameter may be useful. In the authors’ experience, a round urinary bladder that fills most of the caudal abdomen

| Tools | Notes |
|-------|-------|
| **Diagnostic tool** | | |
| Complete history and physical examination | Voiding habits may provide information to suggest urolithiasis. |
| Urinary ultrasound | Renal and bladder ultrasound are useful to diagnose, prognosticate, and plan surgical intervention in cases of urolithiasis. |
| Abdominal radiographs | Useful to differentiate some gastrointestinal conditions from urolithiasis and image radio-opaque uroliths. |
| Fluoroscopy | Potentially useful to diagnose urinary strictures. |
| Penile exam and passage of urethral catheter | Important to diagnose and locate urethral calculi for surgical planning. |
| Abdominocentesis | Occasionally therapeutic for sandy impactions of the distal penile urethra. |
| Serum biochemistry: creatinine and BUN | Useful for differentiating fluid types if abdominal effusion is present. |
| Urinalysis | May support diagnosis of urinary obstruction and aid in prognostication, particularly when performed serially. |
| Urolith analysis | Crystals may provide preliminary evidence of urolith type; may be useful to determine if chemolysis is possible. |
| Therapeutic tools | | |
| Lumbosacral epidural | Potentially useful aid in penile exteriorization for difficult cases. |
| Cystocentesis | Not generally recommended if urine will be sampled during surgical intervention or percutaneous catheter placement. May provide temporary decompression prior to other interventions; however, may lead to urine leakage into abdomen. |
| Percutaneous bladder catheterization | Useful technique for temporary urinary diversion when surgical tube placement is not urgently possible or patient requires medical stabilization prior to surgical intervention. |
| Tube cystostomy | Ideal surgical intervention to remove uroliths from the bladder and provide postoperative urinary diversion during healing. |
| Dietary management to specific to urolith type | May be used for urolith prevention. |
is indicative of abnormal distention, although it should be noted that swine can have a surprisingly large bladder if they need to urinate but are not necessarily obstructed; walking patients to a separate area from their housing may facilitate voluntary voiding when in question. Halland et al reported that potbellied pigs with obstructive urolithiasis had a urinary bladder diameter of 6 to 12 cm, with an average diameter of 9.5 cm. Similarly, review of recent cases admitted to one referral institution revealed that the intact distended urinary bladder in pigs with urinary obstructions can measure 10 to 12 cm in diameter (KM Simpson, DVM, MS, DACVIM, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, unpublished data, 2021). Further evaluation of the urinary bladder may reveal hyper-echoic flecks within the lumen of the urinary bladder. Uroliths are mineral density, and when they accumulate in the ventral portion of the urinary bladder, a focal hyperechoic zone with a prominent acoustic shadow that originates from the mucosal surface may be seen. The abdomen can be evaluated for presence of free fluid that could indicate transmural leakage of urine across a compromised urinary bladder wall (the bladder then still appears tightly distended) or else ruptured urinary bladder (in these cases the bladder appears small and surrounded by fluid).

Radiography
Survey radiography may help identify radiopaque uroliths, facilitate surgical planning, and differentiate between urinary obstruction and some GI disorders. However, not all uroliths in pigs are visible radiographically. For example, one study found that apatite calculi were not visible on survey radiographs in potbellied pigs. In general, uroliths that dissolve in an acidic environment are not radiopaque or are small enough (sabulous uroliths) that they cannot be identified due to summation from other structures. In small ruminants, common radiopaque uroliths include calcium carbonate, calcium oxalate, and silica, and in the authors’ clinical experience, the same is true in pigs. Contrast radiography or fluoroscopy can also be useful for localizing uroliths and elucidating the cause of unresolved urethral obstruction. A tube cystostomy can provide an ingress for contrast medium, as exteriorization and catheterization of the penis in miniature pigs, particularly obese barrows, can sometimes be extremely difficult.

Sedation/anesthesia for diagnostic procedures
When examining pigs, many diagnostic procedures must be done under heavy sedation or general anesthesia. Pig patients have been described as “screaming torpedoes with no handles,” and it can be difficult to safely or effectively restrain them without the use of sedation. Most pet pig owners, even those that own commercial breed swine as pets or rescues, are averse to the use of manual restraint with a hog snare. A sedation protocol the authors frequently use is midazolam (0.2 mg/kg) and butorphanol (0.2 mg/kg) injected IM in the neck (Table 2) where the point of the ear would be located if pressed flat against the neck. After 10 to 15 minutes, pigs are usually sedate enough to induce anesthesia with isoflurane via mask. Suspected malignant hyperthermia has been reported in a miniature potbellied pig following isoflurane anesthesia; although not frequently described in pet pig breeds, this should be discussed with clients prior to anesthetic events, and consent for sedation or general anesthesia should be obtained. If the planned procedures will take more than 30 minutes or the pig has eaten in the past 12 hours, orotracheal intubation should be considered. Swine have a pharyngeal diverticulum that can make intubation more challenging if a stylet is used as a guide to place the endotracheal tube and unintentionally enters this diverticulum. Use of a laryngoscope with a long blade, or even endoscopy, is important to confirm correct tube placement. The authors prefer not to use injectable anesthetic protocols that contain α₂-adrenoceptor agonists in cases of suspected urinary obstruction (including xylazine, detomidine, and dexmedetomidine), as this drug class can result in diuresis and possible rupture of the urinary bladder. A complete review of miniature companion pig sedation and anesthesia has previously been published.

IV access and bloodwork
Most miniature breeds of swine require sedation or anesthesia to obtain a blood sample. An auricular vein can be used to obtain blood using a 25- to 19-gauge, 0.75-inch winged infusion set with a 12-inch extension (often known as a “butterfly catheter”). A small syringe (1 to 3 mL) should be used so as not to collapse the vessel with excessive negative

Table 2—Common chemical restraint/sedation techniques for pigs with urolithiasis.

| Drug and dosage (mg/kg) | Route | Note |
|------------------------|-------|------|
| Midazolam: 0.2–0.4 mg/kg | Midazolam: IM in the neck | Injectable sedation first may allow ease of handling; mask isoflurane can be added as needed to supplement chemical restraint for brief procedures. |
| Isoflurane: apply to effect | Isoflurane: mask | |
| Midazolam: 0.2 mg/kg | Both IM in the neck | Injectable sedation first may allow ease of handling; mask isoflurane can be added as needed to supplement chemical restraint for brief procedures. |
| Butorphanol: 0.2 mg/kg | | |
| Midazolam: 0.2 mg/kg | Intranasal | Midazolam may be squirited up the snout of pigs that are not able to be handled for injection. Intranasal sedation first may allow ease of handling; mask isoflurane can be added as needed to supplement chemical restraint for brief procedures. |
pressure, and a rubber band can be placed at the base of the ear as a tourniquet and secured with a hemostat if needed. This is also a good location to place an IV catheter. If IV catheterization is desired, it is ideal to avoid drawing blood from the ear prior to catheter placement. In many adult pigs, it is possible to place a 22- to 20-gauge, 1- to 1.88-inch IV catheter, but some patients may require a smaller catheter. If a rubber band is used as a tourniquet, remember to cut this and remove it once the catheter is placed. Once placed, it is recommended to secure the catheter well using medical tape, super glue, and potentially surgical staples. A roll of 4 X 4 gauze can be made and taped to secure the gauze together, placed in the ear to help prevent the catheter or pinna from kinking, and secured with elastic tape. It is often very difficult to obtain blood from an auricular vein catheter in pet swine. Inform owners that hematomas could develop following this procedure.

If the pig is completely anesthetized, a lateral saphenous vein catheter can also be placed following a small surgical incision down to the lateral saphenous vein. Blood can usually be obtained repeatedly from a lateral saphenous vein catheter. Alternatively, blood can be obtained from a cephalic vein or from the tail vein as in a bovine. Blood can also be obtained from the jugular vein; however, this is more difficult than many other species due to large amounts of fleshy covering and usually a lack of visible or palpable jugular furrow; due to this anatomy, inadvertent tracheal perforation or laceration of other structures in the neck is a risk, and jugular phlebotomy in pet swine is generally only recommended when patient conformation permits jugular vein identification and/or benefits outweigh the risks of the procedure. In cases of urinary obstruction, as in other species, a serum biochemistry analysis may be helpful to identify azotemia, electrolyte imbalances such as hyperkalemia, and acid-base derangements and to help estimate hydration. In the authors’ experience, patients with acute urinary obstructions may have minimal to no alterations from reference intervals in some of these values. Patients with urinary tract rupture, in particular rupture of the urinary bladder, may alternatively have alterations far exceeding the reference interval in some of these values necessitating immediate treatment.

**Penile exteriorization and urethral catheterization**

Exteriorization and examination of the penis may be performed with the pig under anesthesia. Similar to ruminants, pigs have a sigmoid flexure that must be straightened to exteriorize the penis. This can be facilitated by pulling both hind limbs cranially with the pig in lateral recumbency and having an assistant apply cranially directed pressure at the level of the sigmoid flexure. Caution should be used if traction is applied to the limbs to facilitate positioning; luxation of pig appendicular joints is possible with manual traction and should be avoided. The penis can then be grasped through the skin and subcutaneous tissues while the preputial skin is simultaneously retracted caudally. Although this technique works to exteriorize the penis in most pigs, in pigs that are obese this may not be possible. The penis should be exteriorized in the same plane as natural penile extrusion would occur (do not bend the penis), and gentle tension should be kept on it by an assistant using the gauze wrap to maintain the sigmoid flexure in a straightened position during catheter passage.

In ruminants, use of surgical instruments can assist with penile exteriorization when necessary. Hemostats can be used to gently grasp the internal preputial mucosa and advance it cranially a few millimeters to a centimeter at a time until the glans can be identified. Pigs have a preputial diverticulum in the dorsal aspect of the cranial preputial cavity that can make entrance into the preputial cavity with an instrument more challenging. It should be noted that the free end of the penis in swine is corkscrew shaped. If the penis can be exteriorized, grasp it securely by wrapping an unfolded 4 X 4 gauze around the penis just cranial to the preputial attachment. A quick preparation of the glans using a dilute antiseptic prep solution should be done before any attempt to pass a catheter up the urethra. Retrograde catheterization of the urethra can be done using a 3.5-French closed-ended urethral catheter. For cases with gritty, sand-like urolith impactions of the very distal urethra, an open-ended flushing catheter may more easily flush such obstructions and be therapeutically in addition to diagnostic. After catheter passage, a very small volume (approx 0.2 mL) of 2% lidocaine mixed with a sterile lubricant can be instilled into the urethra. If the catheter can be advanced without resistance, additional small amounts of lidocaine and lubrication can be instilled as the catheter is advanced. Retrograde urethral catheterization and flushing should be done with extreme caution as the urethra is often friable and can easily rupture. If the full length of the catheter can be easily passed without encountering any resistance, it can be removed and a 5- to 8-French canine polypropylene catheter can then be passed, as these are longer than the Tom cat catheters and can usually reach the level of the urethral diverticulum.

Urethrohydrodipsion is not generally recommended as uroliths are likely to be flushed into the urethral recess rather than into the urinary bladder and can then fall back into the urethra and cause reobstruction at a later time.\(^2\) If resistance to passage of the catheter is encountered, the catheter should be marked at the level of the urethral orifice so that the clinician can determine where along the urethra the obstruction is located once the catheter is removed. This can be done by laying the catheter on the outside of the patient at the level of the urethral orifice and then laying the catheter against the patient following the expected natural course of the penis. The general location of the obstruction can then be identified externally. If time and patient condition allow for it, use of radiography for this purpose could also be considered. It should be noted that pigs
have a urethral recess or diverticulum at the level of the ischial arch similar to ruminants. As a result, it is nearly impossible to catheterize the urinary bladder in pigs using a straight urinary catheter. A potential complication of urethral catheterization or other urethral trauma in pigs that appears to be fairly unique to this species is the development of urethral polyps at the level of the urethral recess. This has been described in 2 Vietnamese potbellied pigs following treatment of obstructive urolithiasis in which urethral catheterization was performed repeatedly. This may warrant limiting the number of attempts at catheterization in swine, either prior to or during surgery so as not to traumatize the urethra and possibly create a subsequent obstructive polyp.

**Urinalysis**

Urinalysis and urine sediment exam can be useful in cases where urine is collected during the diagnostic workup or at the time of surgical intervention. The presence of crystalluria is variable, but when present, the type of crystals can help inform clinical decision-making. The authors have generally not attempted to perform a cystocentesis solely to obtain urine for urinalysis as the risk of subsequent urine leakage into the abdomen likely outweighs the benefits. However, ultrasound-guided cystocentesis could be employed prior to a surgical procedure such as cystotomy and/or tube cystostomy to help prevent urinary bladder rupture. Normal urinalysis values in miniature pigs are reported as follows: urine specific gravity, 1.010 to 1.050; urine pH, 5 to 8; protein, negative to trace; RBCs/hpf, 0 to 5; WBCs/hpf, 0 to 5; crystals, common and occasionally pathologic, calcium oxalate, or triple phosphate; and bacteria, numerous in voided samples, significant if numerous WBCs also present. Rupture or substantial leakage of the urinary bladder generally necessitates surgical treatment if treatment is pursued.

**Urolith analysis**

Determining urolith composition is critical in creating a treatment and prevention plan. This can be done based on identification of crystals from a urinalysis or urolith analysis. As presence of crystalluria can be variable and uroliths may be composed of multiple urolith types, the authors prefer submitting uroliths to the Minnesota Urolith Center. There they analyze urolith composition and provide a report to the veterinarian at no charge, although monetary donation is strongly encouraged. In a retrospective study evaluating types of uroliths identified in potbellied pigs, the most common urolith composition was amorphous magnesium calcium phosphate, followed by apatite, struvite, and calcium carbonate or calcium oxalate (in equal numbers). In commercial swine breeds, calcium phosphate, struvite, and a mixed urolith type were most commonly reported. Phosphatic (struvite, apatite, and potentially amorphous magnesium calcium phosphate) uroliths may be dissolved in an acidic solution; calcium carbonate and calcium oxalate uroliths are resistant to chemical dissolution. In the authors’ experience, nondissolvable stones have to be removed surgically. If multiple uroliths can be collected from a patient, it can be helpful to submit one for analysis and place another in a small amount of vinegar and monitor over the next 12 to 24 hours to see if it dissolves. This simple clinic test can quickly indicate whether any remaining uroliths are amenable to chemical dissolution and guide the decision to include urine acidification in the treatment plan while urolith analysis is pending.

**Therapeutic Interventions**

Treatment of obstructive urolithiasis in pigs shares many similarities to that in small ruminants. In this June, 2022 JAVMA Supplemental Issue; See, S64-S71.

**Lumbosacral epidural**

A lumbosacral epidural can be performed between L6 and S1 as an adjunct to general anesthesia prior to surgery and/or to facilitate exteriorizing the penis. A lumbosacral epidural must be performed aseptically to avoid possible contamination of the CSF if the needle is advanced to the subarachnoid rather than epidural space. Lidocaine (2%) can be administered into the epidural space at 1 mL/9 kg, not to exceed a 20-mL volume. A 20-gauge, 6- to 8-cm spinal needle may be used in pigs up to 30 kg; an 18-gauge, 10-cm needle can be used in pigs 35 to 90 kg; and a 16-gauge, 12- to 16-cm needle used in pigs over 90 kg. The lumbosacral space should be clipped and aseptically prepared prior to performing this procedure, which has been described elsewhere in detail.

**Urinary diversion**

Medical or noninvasive treatment alone is rarely successful in pigs, and surgical intervention is often necessary based on the authors’ experience. An intact urinary bladder is necessary if a less invasive or minimally invasive approach to treatment and urinary egress is to be utilized, rather than surgical management. Ultrasound-guided placement of a temporary percutaneous catheter (Bonnano, Becton, Dickinson & Co) into an intact urinary bladder can allow for medical stabilization of a patient prior to surgery under general anesthesia. Additionally, this temporary catheter placement may allow time for the patient to be referred to another facility for surgical treatment or else to avoid costs associated with after-hours surgery by allowing surgical intervention to occur during normal business hours. Most pigs that undergo this specific procedure are reported to require a subsequent surgical procedure to resolve urinary obstruction, and catheter occlusion is a reported complication in this species. However, in cases with uroliths that can dissolve in acidic solution, it may be possible to administer an oral urinary acidifier or directly instill buffered acetac acid (Walpole’s Solution, Jorgensen Labs) or buffered citric acid (Renacidin, Guardian Laboratories) into the urinary bladder via the urinary catheter and dissolve cystic and/or urethral calculi. A similar procedure using a 16-French Foley catheter
introducer (Introducer Lawrence Supra-Foley 16 Fr, Utah Medical) and a 14-French Foley catheter has been used by one of the authors (KMS) to percutaneously place a cystostomy tube in the left inguinal region via ultrasound guidance in a potbellied pig with struvite urolithiasis. Following urinary acidification with ammonium chloride for 7 days, the pig was able to urinate normally and the tube was removed. This patient had economic constraints and was able to be treated effectively within the available budget without surgical intervention.

**Surgical intervention**

The most well-described surgical treatment for obstructive urolithiasis in pigs is cystotomy with tube cystostomy. Celiotomy with primary repair of the urinary bladder, removal of any remaining cystoliths, and placement of a tube cystostomy is ideal in cases of ruptured urinary bladder and when nondissolvable uroliths are known or suspected to be within the urinary bladder. Cystostomy tubes are left in place for a minimum of 7 to 10 days prior to removing the tube even if urethral patency is achieved sooner. This allows for an effective fibrin seal to form between the urinary bladder and the body wall and prevents leakage of urine into the abdomen from the site of tube placement once the tube is removed. The stoma created by smaller percutaneous catheters (Bonnano, Becton, Dickinson & Co) placed to provide temporary urinary egress appear to seal over more quickly and do not necessitate being maintained as long as larger catheters, which is advantageous since these tubes often kink, plug, or otherwise fail within hours to days of placement.

Cystotomy and tube cystostomy, which have previously been described in detail and are considered the gold standard treatment of obstructive urolithiasis, are very successful in the short-term but can be fraught with long-term complications in 50% of pigs. Reobstruction, cystitis, and urethral stricture were reported in these cases. However, this is still considered the best treatment option available and is likely to be the only option in cases with uroliths such as calcium carbonate that are refractory to dissolution. In breeding boars, this would be the surgical option most likely to return the animal to breeding soundness, as urethral integrity and function are not affected by this procedure. The authors do not perform retrograde urethral catheterization or flushing during the tube cystostomy procedure in pigs, as any content leaking from the preputial diverticulum into a surgical site could have catastrophic consequences; a purse-string suture is placed at the preputial orifice prior to this surgery and should be removed prior to recovering the patient from anesthesia. Pigs with tube cystostomies should remain on effective antimicrobials at least until the tube can be removed, and based on work in goats, 103 of 103 goats with tube cystostomies were positive on bacteriologic culture of the urine from the catheter tip at the time of removal.

In the authors’ experience, targeted urethrotomy may be required in addition to cystotomy and tube cystostomy to remove urethral calculi such as calcium carbonate that do not dissolve in acidic solutions. A possible alternative to this is urethroscopy and laser lithotripsy if the appropriate equipment is available; however, attempts at retrograde urethroscopy resulted in breakage of the cystoscope in 1 report.

Proximal perineal urethrostomy has been performed in a pig with a urethral stricture; this was modeled after the modified proximal perineal urethrostomy in goats. This may be an option in pigs with obstructive urolithiasis provided it could be performed proximal to any urethral calculi or proximal to the site of a urethral rupture; however, a subsequent report in goats indicated that 40% had significant hemorrhage following this procedure. Chigerwe et al reported that urinary calculi in pigs were most often found in the urinary bladder only (44%), urethra only (28%), and urinary bladder and urethra (20%); this would suggest that most pigs would require removal or else dissolution of cystoliths in addition to urethroliths. Patients considered good candidates for a perineal urethrostomy would generally include those in which cystic uroliths were either small enough to pass through the rerouted proximal urethra or else amenable to dissolution. In general, perineal urethrostomy in goats has a low long-term success rate with 52% reported to be alive at the time of follow-up (mean 34 months postsurgery) and 32% developing strictures at the urethral stoma site. Perineal urethrostomy therefore may be a poor choice in pet pigs in which longevity is desired.

Prepubic urethrostomy, extrapelvic urethral, and urethropreputial anastomosis have been described in Vietnamese potbellied pigs; these procedures appear to be complex and potentially challenging to perform. Use of minimally invasive percutaneous cystolithotomy has recently been described in a potbellied pig with a proximal urethral obstruction.

**Medical management**

Medical treatment that precedes or accompanies surgical treatment of obstructive urolithiasis in pigs often includes IV fluid therapy, antimicrobials, analgesics, urine acidification, and antacids or antiemetics. The authors have generally used dosage regimens intended for monogastrics such as dogs if regimens for swine have not been described. The AMDUCA must be followed in all pigs, and the Food Animal Residue Avoidance Databank should be contacted prior to any extralabel use of medications in pet swine because they are still considered a major food-producing species in the United States regardless of their status as a pet or rescue animal. Nonsteroidal anti-inflammatories such as flunixin meglumine for swine or extralabel use of oral carprofen (4.4 mg/kg, q 24 h) or oral meloxicam most often at 0.4 mg/kg, PO, every 24 hours (up to 0.5 mg/kg, PO) should be used judiciously and ideally after azotemia has been resolved and renal perfusion restored. Most oral medications can be given in small treats to facilitate ease of administration in pigs. Opioids such as
butorphanol or morphine can be used for pain control in hospitalized patients but can cause constipation in pigs, particularly in animals that are also undergoing general anesthesia, and should be used judiciously. Lack of GI motility may be a significant comorbidity in some sick pigs; rehydration and correcting electrolyte or acid-base disturbances may improve GI motility. Oral prokinetics such as cisapride or metoclopramide have been used for this purpose in pet pigs although efficacy is questionable. Oral proton pump inhibitors including omeprazole or H2-receptor blockers such as famotidine could be administered to pigs with a history of concurrent anorexia or vomiting, as pet pigs often display signs consistent with gastric ulcers as a comorbidity to many other painful or stressful conditions. Pigs with a history of vomiting may also benefit from extralabel use of maropitant, particularly prior to general anesthesia. Acetpromazine or prazosin may help address urethral spasm but has not been studied in pigs to the authors’ knowledge. It should be noted, however, that in this June, 2022 JAVMA Supplemental Issue (See, S7–S11), prazosin administration in cats has been shown to increase the rate of recurrent urethral obstruction.24 Broad-spectrum antibiotics that are excreted in the urine and can be administered orally, such as amoxicillin trihydrate (6.6 to 22 mg/kg, PO, q 12 to 24 h),25 may be easier for clients to give at home compared with injectable antimicrobials. The authors have most often used the high end of this dosing regimen twice per day. The authors have used ammonium chloride for urinary acidification at 200 mg/kg/d, PO (often divided into a twice-a-day treatment regimen) as described in ruminants and found it to be effective in pigs. Urine pH can be monitored by clients at home using pH strips to tailor treatment appropriately; the target urine pH is usually 5.5 to 6.5 to prevent urolithiasis50 with uroliths that form in alkaline urine. In goats, urinary acidification with ammonium chloride increases the fractional excretion of calcium;53 it is unknown if this occurs in swine; therefore, it could be contraindicated in pigs with calcium-containing uroliths such as calcium carbonate. Pulse dosing of ammonium chloride is recommended to avoid tachyphylaxis particularly if administered long term. A commercially available canine urinary acidification diet was reportedly used successfully in a Visayan warty pig;52 the authors have no experience with use of small animal diets for this purpose in swine.

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References

1. Chigerwe M, Shiraki R, Olstad EC, Angelos JA, Ruby AL, Westropp JL. Mineral composition of urinary calculi from potbellied pigs with urolithiasis: 50 cases (1982–2012). J Am Vet Med Assoc. 2013;243:389–393.
2. Needleman A, Videla R. Urolithiasis in a female miniature potbellied pig. Vet Rec Case Rep. 2019;7:e000809. doi:10.1136/vetreccr-2018-000809
3. Gamsjager L, Chigerwe M. Risk factors for, frequency, and type of complications after temporary tube cystotomy in goats, sheep, and pigs. Vet Surg. 2021;50:283–293.
4. Tynes VV, Mozzachio K. Miniature pigs. In: Carpenter JW, Marion C, eds. Exotic Animal Formulary. 5th ed. Elsevier; 2018:558–574.
5. Halland SK, House JK, George LW. Urethroscopy and laser lithotripsy for the diagnosis and treatment of obstructive urolithiasis in goats and pot-bellied pigs. J Am Vet Med Assoc. 2002;220:1831–1834.
6. Streeter RN, Step DL. Diagnostic ultrasonography in ruminants. Vet Clin North Am Food Anim Pract. 2007;23:541–574.
7. Kinsley MA, Semevolos S, Parker JE, Duesterdieck-Zellmer K, Huber M. Use of plain radiography in the diagnosis, surgical management, and postoperative treatment of obstructive urolithiasis in 25 goats and 2 sheep. Vet Surg. 2013;42:663–668.
8. Claxton-Gill MS, Cormick-Seahorn JL, Gamboa JC, Boatright BS. Suspected malignant hyperthermia syndrome in a miniature pot-bellied pig anesthetized with isoflurane. J Am Vet Med Assoc. 1993;203(10):1434–1436.
9. Dyce KM, Sack WO, Wensing CJG. The head and neck of the pig. In: Dyce KM, Sack WO, Wensing CJG, eds. Textbook of Veterinary Anatomy. 3rd ed. Saunders; 2002:768.
10. Smith JS, Seddighi R. Miniature companion pig sedation and anesthesia. Vet Clin North Am Exot Anim Pract. 2022;25(1):297–319. doi:10.1016/j.cvex.2021.08.007
11. Ewoldt JM, Jones ML, Miesner MD. Surgery of obstructive urolithiasis in ruminants. Vet Clin North Am Food Anim Pract. 2008;24:455–465.
12. Garrett PD. Urethral recess in male goats, sheep, cattle, and swine. J Am Vet Med Assoc. 1987;191:689–691.
13. Helman RG, Hooper RN, Lawhorn DB, Edwards JF. Urethral polyplys in Vietnamese pot-bellied pigs. J Vet Diagn Invest. 1996;8:137–140.
14. Osborne CA, Albahan L, Lulich JP, Nwakorie E, Koehler LA, Ulrich LK. Quantitative analysis of 4468 uroliths retrieved from farm animals, exotic species, and wildlife submitted to the Minnesota Urothol Center: 1981 to 2007. Vet Clin North Am Small Anim Pract. 2009;39:65–78.
15. Mejia S, McOnie RC, Nelligan KL, Fubini SL. Small ruminant urinary obstruction: decision trees for treatment. J Am Vet Med Assoc. 2022;260(S2):S64–S71.
16. Anderson DE, St. Jean G. Anesthesia and surgical procedures in swine. In: Zimmerman JJ, Karriker LA, Ramirez A, Schwartz KJ, Stevenson GW, eds. Diseases of Swine. 10th ed. John Wiley & Sons; 2012:124–126.
17. Skarda RT. Local and regional anesthesia in ruminants and swine. Vet Clin North Am Food Anim Pract. 1996;12:579–626.
18. Chigerwe M, Heller MC, Balcomb CC, Angelos JA. Use of a percutaneous transabdominal catheter for management of obstructive urolithiasis in goats, sheep, and pot-bellied pigs: 69 cases (2000–2014). J Am Vet Med Assoc. 2016;248:1287–1290.
19. Rakestraw PC, Fubini SL, Gilbert RO, Ward JO. Tube cystotomy for treatment of obstructive urolithiasis in small ruminants. Vet Surg. 1995;24:498–505.
20. Chigerwe M, Mavangira V, Byrne BA, Angelos JA. Antibiotic resistance patterns of bacteria isolated from indwelling Foley catheters following tube cystotomy in goats with obstructive urolithiasis. J Vet Diagn Invest. 2017;29:316–320.
21. Coutant T, Dunn M, Montasell X, Langlois I. Use of percutaneous cistolithotomy for removal of urethral uroliths in a pot-bellied pig. Can Vet J. 2018;59:159–164.
22. Rinnovati R, Lambertini C, Spadari A. Proximal perineal urethrostomy technique for treatment of urethral stricture in a Vietnamese pot-bellied pig. *Veterinaria*. 2017;31(5):1–5.
23. Tobias KM, van Amstel SR. Modified proximal perineal urethrostomy technique for treatment of urethral stricture in goats. *Vet Surg*. 2013;42:455–462.
24. Oman RE, Reppert EJ, Streeter RN, Jones M. Outcome and complications in goats treated by perineal urethrostomy for obstructive urolithiasis: 25 cases (2010–2017). *J Vet Intern Med*. 2019;33:292–296.
25. Mann FA, Cowart RP, McClure RC, Constantinescu GM. Permanent urinary diversion in two Vietnamese pot-bellied pigs by extrapelvic urethral or urethrapreputial anastomosis. *J Am Vet Med Assoc*. 1994;205:1157–1160.
26. Leon JC, Gill MS, Cornick-Seahorn JL, Hedlund CS, Hosgood G. Prepubic urethrostomy for permanent urinary diversion in two Vietnamese pot-bellied pigs. *J Am Vet Med Assoc*. 1997;210:366–368.
27. Pairis-Garcia MD, Johnson AK, KuKanich B, Wulf L, Millman ST, et al. Pharmacokinetics of meloxicam in mature swine after intravenous and oral administration. *J Vet Pharmacol Ther*. 2015;38:265–270.
28. Conway DS, Rozanski EA, Wayne AS. Prazosin administration increases the rate of recurrent urethral obstruction in cats: 388 cases. *J Am Vet Med Assoc*. 2022;260(S2):S7–S11.
29. Constable PD, Hinchcliff KW, Done SH, Grunberg W. Drug doses and intervals for pigs. In: Constable PD, Hinchcliff KW, Done SH, Grunberg W, eds. *Veterinary Medicine: A Textbook of the Diseases of Cattle, Horses, Sheep, Pigs, and Goats*. Vol. 2. 11th ed. Elsevier; 2017:2232–2234.
30. Jones ML, Miesner MD. Urolithiasis. In: Anderson DE, Rings DM, eds. *Current Veterinary Therapy: Food Animal Practice*. 5th ed. Saunders; 2009:322–325.
31. Mavangira V, Cornish JM, Angelos JA. Effect of ammonium chloride supplementation on urine pH and urinary fractional excretion of electrolytes in goats. *J Am Vet Med Assoc*. 2010;237:1299–1304.
32. Chatterton J, Unwin S, Lopez J, Chantrey J. Urolithiasis in a group of visayan warty pigs (Sus Cebifrons Negrinus). *J Zoo Wildl Med*. 2017;48:842–850.