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Original Article

The use of pneumatic impact lithotripsy and a retrieval pouch to create a closed system for removal of cystic calculi in standing male horses

***N. P. De Bernardis*[†]*, K. A. Seabaugh*[‡]*, J. Ismay*[§] *and M. Mudge*[¶]**

[†]*College of Veterinary Medicine, Cornell University, Ithaca, New York;* [‡]*Department of Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, Colorado;* [§]*Sturgis Veterinary Hospital and Equine Center, Sturgis, South Dakota; and* [¶]*Department of Veterinary Clinical Sciences, College of Veterinary Medicine, The Ohio State University, Columbus, Ohio, USA.*
**Corresponding author email: nikhita.p.debernardis@cornell.edu*

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Summary

Multiple techniques exist for removal of cystic calculi in the male horse, some of which use a perineal urethrotomy (PU) to facilitate access to the urinary bladder for removal of small uroliths in the standing, sedated horse. These techniques have limited efficacy in the removal of uroliths that have a diameter larger than the PU site, typically 4–5 cm. Pneumatic lithotripsy as reported in this article provides a novel way to fragment these larger uroliths while containing the fragments and protecting the urethra and urinary bladder. Ten geldings and one stallion underwent a lithotripsy procedure to remove one (n = 10) or several (n = 1) uroliths ranging in diameter from 4 to 9 cm. A PU was performed and a laparoscopic retrieval bag was inserted into the urinary bladder through the PU site. The urolith was manipulated into the bag using blind transrectal manipulation or endoscopic guidance and the opening of the bag was exteriorised out of the PU site. A pneumatic lithotrite was used to fragment the stone. When the urolith was adequately fragmented, the fragments were removed by the use of sponge forceps and by flushing the fragments from the bag with obstetrical lube. This was continued until the bag could smoothly be withdrawn from the urinary bladder. All uroliths were successfully removed. The PU sites healed without complication and none of the horses had recurrence of presenting clinical signs. This article also discusses the difference between two types of laparoscopic retrieval bags. Pneumatic impact lithotripsy in combination with a retrieval pouch offers a safe alternative to other methods for removal of cystic calculi in the horse.

Introduction

The prevalence of urolithiasis in horses is reported to be 0.04–0.5% (Duesterdieck-Zellmer 2007). Calculi can be located anywhere along the urinary tract but are most commonly located within the urinary bladder (Laverty *et al.* 1992). Under normal conditions, horses excrete large amounts of calcium carbonate in their urine (Mair and Osborn 1990). This combined with the alkaline nature of their urine contributes to the formation of two different types of uroliths. Type I uroliths, which make up 90% of equine uroliths, are yellow–green spiculated stones that easily fragment. Type II uroliths, which are less common, are grey–white, smooth stones that are more resistant to fragmentation (Schott 2004). Clinical signs associated with cystic urolithiasis include dysuria and haematuria. Cystic urolithiasis is more commonly found in male horses presumably due to their longer, less distensible urethra. If found in mares, calculi can typically be removed whole via manual dilation of the urethral sphincter or urethral sphincterotomy after epidural anaesthesia, although fragmentation with electrohydraulic or pulsed-dye laser lithotripsy has also been suggested (Divers 2008).

In human subjects, if urinary bladder stones cannot pass naturally, they are typically addressed via transurethral cystolitholapaxy, which involves inserting a cystoscope into the urethra and delivering laser energy or shockwave (Li *et al.* 2015a). The length of the male horse's urethra in combination with the relatively small diameter of an endoscope makes this procedure difficult in horses. Moreover, when using this technique, the fragments are not contained within a surgical bag so would be more likely to irritate the urinary bladder and would potentially act as a nidus for further stone formation. Pneumatic lithotripsy has been reported to fragment renal and ureteral stones in human subjects but extracorporeal shockwave lithotripsy is more commonly used in management of human urolithiasis (Radojevic *et al.* 2009; Li *et al.* 2015b). The ability to break up kidney stones, and less commonly urinary bladder stones, with this technique avoids the need for invasive surgery in human patients (Telha *et al.* 2016). However, extracorporeal shockwave instrumentation in human subjects uses a generator that encircles the abdomen, so unfortunately, the size of the horse precludes the use of true extracorporeal shockwave lithotripsy in the equine cases.

Multiple techniques have been described for removal of cystic calculi in the horse. Cystotomy techniques require general anaesthesia (Beard 2004; Watts and Fubini 2013) or deep dissection of pararectal tissues (Abuja *et al.* 2010). Laparoscopic cystotomies have also been described (Lund *et al.* 2013) as well as laparoscopic-assisted techniques (Rocken *et al.* 2006; Stratico *et al.* 2012; Vitte *et al.* 2013). Complications associated with these techniques are rare but can include abdominal incisional dehiscence, peritonitis, uroperitoneum and incomplete removal of the urolith. Intact and manually fragmented uroliths have been removed through perineal urethrotomy (PU) as a standing procedure in geldings (Laverty *et al.* 1992; Hawkins 2013; Kilcoyne and

Dechant 2014). Complications associated with PU include stranguria, urine scalding, haemorrhage, urethral stricture, perforation of pelvic urethra and recurrence of cystic calculi (Laverty *et al.* 1992; Kilcoyne and Dechant 2014).

The use of radial (Foerner and Stanschi 2005; Katzman *et al.* 2016), ballistic (Koenig *et al.* 1999) and electrohydraulic shockwave (Koenig *et al.* 1999; Rocken *et al.* 2012) have been described in the horse, but all methods of shockwave have notable disadvantages. Ballistic shockwave and radial shockwave in one report (Foerner and Stanschi 2005) involved general anaesthesia, pneumatic radial shockwave in another report involved expensive instrumentation (Katzman *et al.* 2016) and electrohydraulic shockwave required up to six separate sessions. There are also reports of use of a pulsed-dye laser and holmium:yttrium-aluminium-garnet (holmium:YAG) laser to fragment equine uroliths. Both lasers have the disadvantages of expense, increased surgical time to fragment uroliths and incomplete fragmentation for type II calculi (May *et al.* 2001; Judy and Galuppo 2002; Grant *et al.* 2009).

Although anecdotal reports of pneumatic lithotripsy in the horse exist, to the authors' knowledge, there is only one other published report of its use in a group of horses, which uses pneumatic radial shockwave lithotripsy (Katzman *et al.* 2016). Shockwave lithotripsy uses sound waves to fragment uroliths, whereas the current report goes into greater detail to describe the use of a pneumatic impact lithotrite, which uses direct physical contact of a steel rod to fragment uroliths. This report also details two different types of laparoscopic retrieval bags for removal of cystic calculi through a PU. The goal of this study was to report on the success and benefits of pneumatic lithotripsy in combination with a laparoscopic retrieval bag for removal of cystic stones in male horses. We hypothesised that pneumatic lithotripsy would require a shorter surgical time and lower equipment costs than other described methods for removal of cystic calculi in the horse.

Materials and methods

All horses that underwent pneumatic lithotripsy at one of the five participating referral centres for removal of cystic calculi were included in the study. The participating referral centres were Colorado State University (CSU), Sturgis Veterinary Hospital and Equine Center, Ohio State University (OSU), the University of Georgia (UGA) and South Valley Large Animal Clinic. At least one author was physically present for all procedures.

The presence of a cystic calculus was confirmed with transrectal palpation and ultrasonography with or without cystoscopy. Cystoscopy was used if the calculus/calculi could not be well characterised ultrasonographically in terms of size and number. The diameter of the stone was measured ultrasonographically. Feed was withheld from all horses for 8–24 h prior to surgery. This range is due to differences between institutions, with the longer end of the range attempted in order to decrease the amount of faecal material in the rectum during surgery. Preoperatively, all horses were administered flunixin meglumine (Prevail™[1], 1.1 mg/kg bwt, i.v.) and a broad spectrum antibiotic (either trimethoprim-sulfonamide (Sulfadiazine 12.5/Trimethoprim 2.5 gm per 30 mL[2] or Bactrim® DS[3], 30 mg/kg bwt, oral [PO]) alone or potassium penicillin G (Pfizerpen®[4] 22,000 U/kg bwt, i.v.) and gentamicin sulfate (Gentafuse[5] 6.6 mg/kg bwt, i.v.) together). The horses were sedated with butorphanol tartrate (Torbugesic®[6], 0.01 mg/kg bwt, i.v.) and detomidine hydrochloride (Dormosedan®[4], 0.01 mg/kg bwt, i.v.). A level plane of sedation was maintained with either a continuous infusion of detomidine hydrochloride (20 mg/L) or butorphanol tartrate (10 mg/L) in sodium chloride (0.09%), at a rate of approximately 1–2 drops per second (10 drops/mL) or additional i.v. boluses of detomidine hydrochloride and/or butorphanol tartrate as needed. Epidural anaesthesia was performed at the sacrococcygeal or first intercoccygeal space. A 20-gauge, 3.8 cm (1.5 inch) needle was used, and xylazine (Anased®[7], 0.75 mL; 100 mg/mL) and mepivacaine hydrochloride (Carbocaine®-V[8], 4.25 mL; 20 mg/mL) were injected into the epidural space.

The penis was cleaned with chlorohexidine scrub and saline (0.09% NaCl). A urinary catheter was placed using aseptic technique. The urine was drained from the urinary bladder and the catheter was left in place. The rectum was evacuated of feces and then infused with lidocaine HCl[9] (20 mg/mL, 50 mL); if any strong rectal contractions were encountered during rectal palpation the horse was also administered a single dose of *N*-butylscopolammonium bromide (Buscopan™[10], 0.2–0.3 mg/kg bwt, i.v.; 20 mg/mL). The perineal region was clipped and prepared for aseptic surgery.

A PU was performed level with, and just proximal to, the ischial arch. The urinary catheter was palpated to determine the location of the urethra. A No. 10 blade was used to create a 5 cm vertical incision through skin and subcutaneous tissue. Curved Metzenbaum scissors were used for blunt dissection through the subcutaneous tissues. Once the urethra was isolated, a No. 10 scalpel blade was used to create a 4 cm incision into the urethra. The urinary catheter was then removed from the urethra.

A sterile 9.6 mm, 1 m endoscope was used to visualise the bladder in some cases. The laparoscopic retrieval bag (Retrieval bag[11] or Endo Catch™ II[12], **Fig 1**) was inserted into the urinary bladder via the PU and the bag was deployed. The stone was placed into the bag by one of two methods: (1) transrectal manipulation of the stone (blind, **Fig 2**) or (2) under endoscopic guidance (endo, **Fig 3**). The endoscope was removed from the urinary bladder once the urolith was secured within the retrieval bag. With the urolith secured in the laparoscopic retrieval bag, the opening of the bag was exteriorised through the PU (**Fig 4**). The interior of the bag was then lubricated with obstetrical lube (n = 9, Lubrivet[13]) or sterile lube (n = 2, Surgilube[14]).

The lithotripsy instrumentation consists of a stainless steel rod (pneumatic impact lithotrite) that is 0.5 inches in diameter, a pneumatic scaler, a regulator with associated air lines and a gas source (**Fig 5**). The rod is 18 inches long. The surgical end is blunt. The opposite end is designed such that it fits into a pneumatic scaler[15] (E in **Fig 5**). Once mounted into the pneumatic scaler the vibrating action causes the urolith to break apart when in contact. The scaler used vibrates at 4000 beats/min with 0.25 inch strokes. This air scaler requires connection to a gas line with 90 psi.

The surgical end of the pneumatic impact lithotrite was passed into the exteriorised opening of the laparoscopic retrieval bag and the end of the lithotrite was held firmly in contact with the urolith. The urolith was stabilised against the rod transrectally. The urolith was fragmented by activating the lithotrite in short bursts while continuing to stabilise the

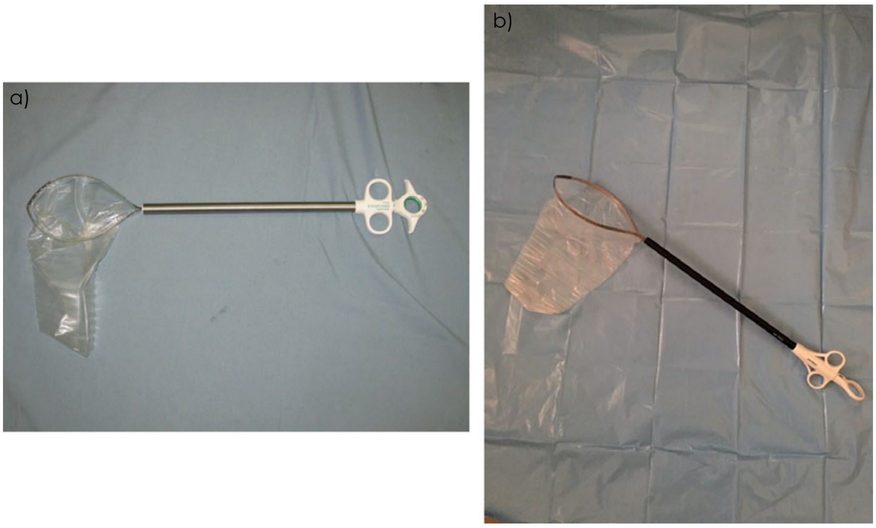

***Fig 1:** Laparoscopic retrieval bags (a) Endo Catch™II and (b) thicker Mila bag.*

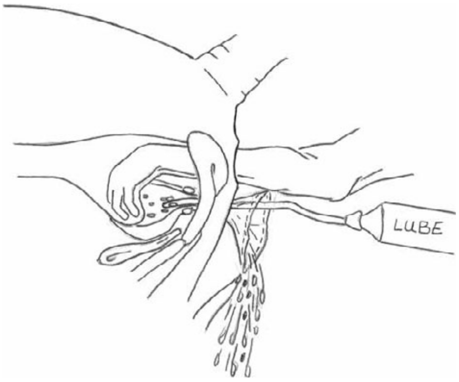

***Fig 2:** Drawing of laparoscopic retrieval bag positioned through the perineal urethrotomy site and securing the urolith with transrectal manipulation.*

urolith transrectally (**Fig 6**). The fragmentation process was monitored by transrectal palpation and applying gentle traction on the retrieval pouch. Frequently, the lithotrite was removed from the pouch to allow lavage of the fragments from the laparoscopic retrieval bag. The bag was infused with obstetrical lube[13,14] in sufficient quantity to lavage out the small pieces of the urolith. Sponge forceps were also used to remove larger fragments. The obstetrical lube[13,14] was infused into the pouch using a 60 mL catheter tip syringe and a 30 cm section of a stallion catheter. Additional fragmentation was performed if necessary. The retrieval pouch was removed from the urinary bladder when a sufficient quantity of the fragments had been flushed from the retrieval pouch opening to allow its passage through the urethra (**Fig 7**).

Upon removal of the retrieval bag and urolith fragments (**Fig 8**), a cystoscopic examination was performed to detect if there were any remaining calculi or fragments. If additional calculi were identified, the procedure was repeated until the urinary bladder was free of calculi. If any fragments were present within the urinary bladder, it was lavaged with isotonic fluids. In some cases, fragments were removed using instrumentation (laparoscopic grasping forceps) and direct visualisation with the endoscope. When all calculi had been successfully removed, the urinary bladder and urethral mucosa were assessed with the endoscope. The PU incision was left to heal by second intention.

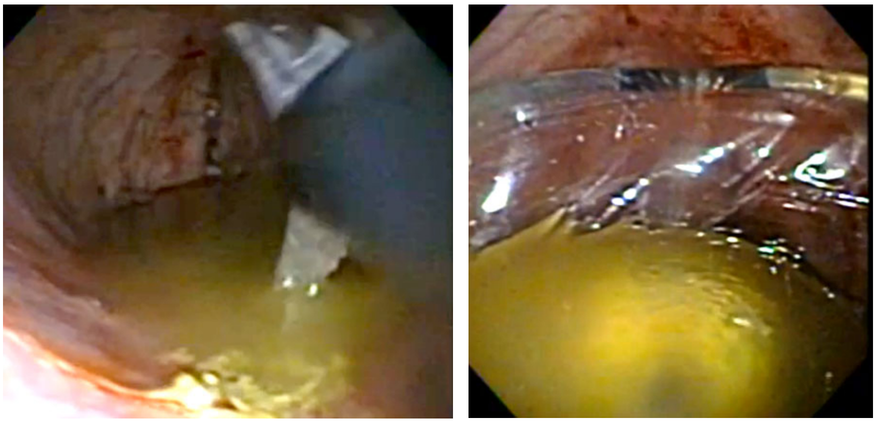

***Fig 3:** A laparoscopic retrieval bag positioned through the perineal urethrotomy site and securing the urolith with endoscopic guidance.*

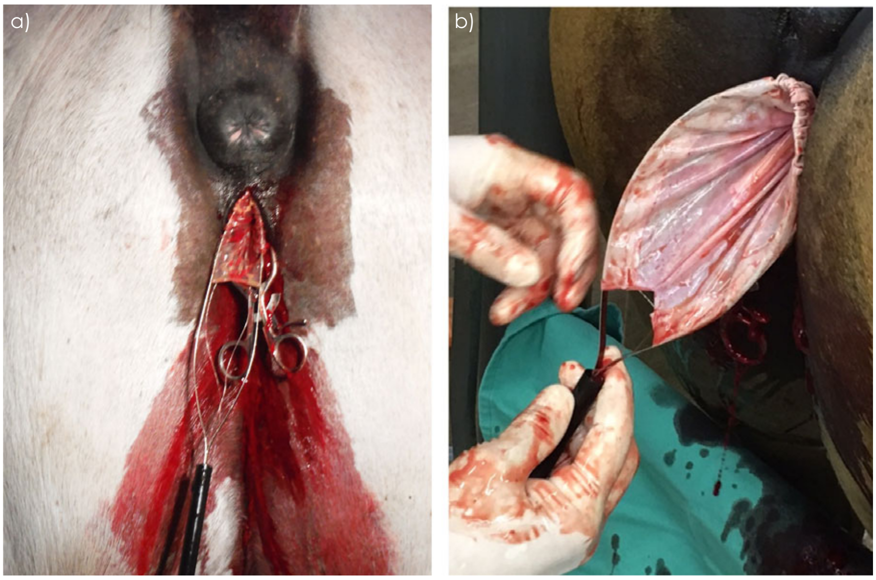

***Fig 4:** Opening of laparoscopic retrieval bag secured at the perineal urethrotomy site. a) using Endo Catch II b) using thicker Mila bag.*

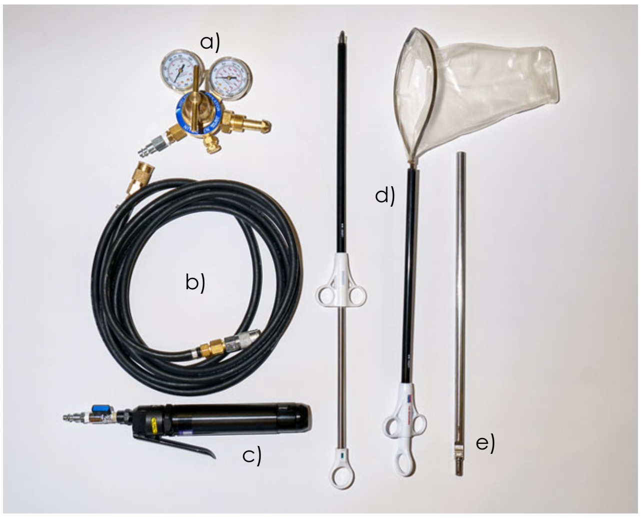

***Fig 5:** Components of the pneumatic lithotripsy equipment. a) Gas regulator, b) Gas line, c) Pneumatic scaler, d) laparoscopic retrieval bags, e) stainless steel lithotrite.*

The horses remained hospitalised for a minimum of 1 day post-operatively. They remained on an oral trimethoprim-sulfonamide[2,3], (15–30 mg/kg bwt, PO) twice daily for 5 days and received phenylbutazone (Bute Boluses[16], 2.2 mg/kg bwt, q 12 h, PO) for 3–5 days following surgery. The PU site was cleaned daily with warm water. Petroleum jelly was applied distal to the incision after each cleaning to prevent urine scald. The owners were instructed to watch for bleeding from the site, abnormal swelling or discharge.

Results

Eleven horses underwent pneumatic lithotripsy (Sturgis (5), CSU (3), OSU (1), UGA (1) and South Valley (1)). The mean age was 15.5 years (range 5–22 years). The horses weighed between 400 and 660 kg. Ten horses had a single urolith and one horse had multiple uroliths present within the urinary bladder. Urolith diameters ranged from 4 cm to 9 cm. Only the largest urolith was measured in the horse with multiple uroliths present. Preoperative medications included antibacterial coverage with a trimethoprim-sulfaonamide (n = 9) or potassium penicillin and gentamicin (n = 2) as well as flunixin meglumine for control of pain and inflammation. All horses received epidurals before the PU was performed and were continued for 5 days post-operatively on a trimethoprim-sulfonamide and phenylbutazone.

All calculi were successfully removed. The urolith was manipulated into the laparoscopic retrieval bag transrectally in eight horses and endoscopy was used in three horses. The Mila retrieval bag was used in six cases and the Endo Catch II laparoscopic retrieval bag was used in five cases. The laparoscopic retrieval bag developed holes in two of the cases and the urinary bladder had to be lavaged to remove all fragments in these cases. The mean surgical time from the start of the PU incision to extraction of the laparoscopic retrieval bag with urolith contents was 68.1 min (range 48–110 min). The mean lithotripsy time (from the time the stone was contained within the bag to when the bag was extracted) was 37.9 min (range 25–60 min) for nine horses. Surgery time was not recorded for two horses.

Follow-up information was available for 10 of the 11 cases (2 months–4 years post-operatively, mean = 497 days, median = 391 days). All 10 horses had returned to full work. Owners reported no recurrence of clinical signs of urinary pathology. At the time of publication, three of the 11 horses had died, two of completely unrelated causes and one of unknown causes. In all cases, the PU sites had healed without complication.

Discussion

This report describes the use of pneumatic impact lithotripsy and a laparoscopic retrieval bag for the removal of cystic

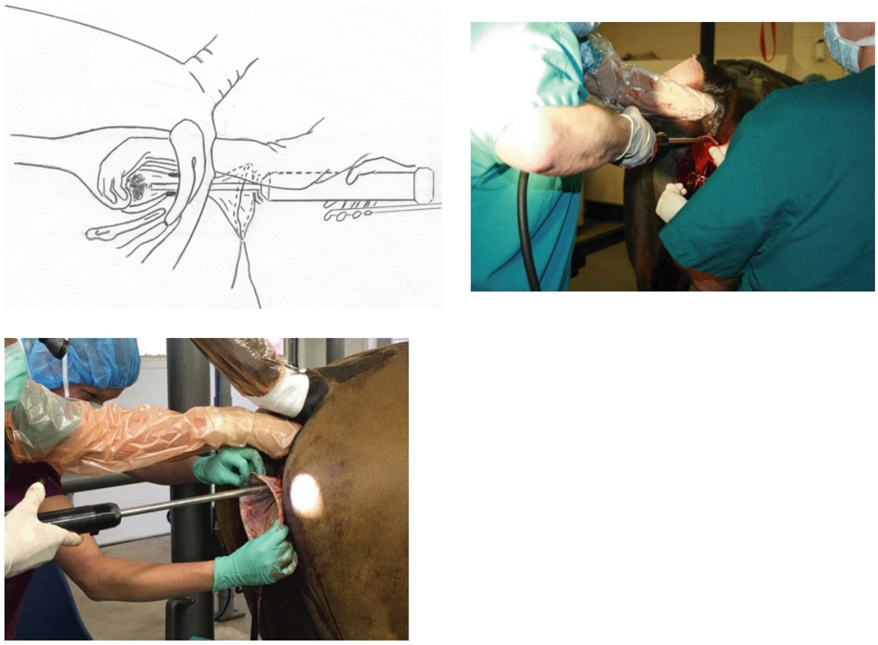

***Fig 6:** Drawing and pictures depicting activation of the pneumatic lithotrite against the urolith while stabilising the urolith transrectally.*

***Fig 7:** The retrieval pouch after removal with fragmented stone inside.*

***Fig 8:** A fragmented urolith after removal from the retrieval bag.*

calculi through a PU in the standing gelding and stallion. A total of 11 horses were reported in this study.

The pneumatic impact lithotrite used in the current study is a novel device for manual lithotripsy in horses. The lithotrite is a smooth, steel rod that can be advanced through the PU site into the urinary bladder with little to no resistance. The rod can also be readily palpated transrectally allowing for positioning of the stone against the rod. The vibration of the rod quickly fragments type I uroliths and type II uroliths require slightly more fragmentation. The rod can be sterilised. The pneumatic scaler can also be sterilised using gas sterilisation. The instrumentation requires minimal maintenance in the form of compressor and air tool lubricant after each use. This piece of equipment requires some experience to gain comfort with but once used a few times becomes uncomplicated to manipulate.

The laparoscopic retrieval bag plays an important role in the success of this technique because it contains the urolith fragments and protects the urethra. In previous cases, fragmentation of the urolith into the bladder lumen then required a more extensive lavage of the bladder following lithotripsy. This leads to increased bladder and urethral mucosal irritation. The use of a laparoscopic retrieval bag has been described previously (Menendez and Fitch 2012; Katzman *et al.* 2016), but in one report the uroliths were less than 5 cm in diameter and in the other a pneumatic impact lithotrite was not used, leading to prolonged surgical times.

The laparoscopic retrieval bag does add a level of technical difficulty. In the two cases where the retrieval bags developed holes, the bags were in the early stages of development for this procedure and were manufactured of a thinner material. In those cases, fragments were found within the urinary bladder following extraction of the bag and more extensive lavage of the urinary bladder was required to remove the remaining fragments. It is also important that the bag is fully deployed prior to scooping the urolith. Full deployment allows the stone to pass to the most ventral portion of the bag. The opening of the bag is then exteriorised. One laparoscopic retrieval bag has fenestrations at the attachment to the ring. These fenestrations can tear free prematurely. Other models of the laparoscopic bag do not possess these fenestrations and have greater integrity at the ring. Bag strength is also important. As the urolith breaks apart, the fragments assume a grit-like texture, which can create holes within the bag, especially with type II uroliths which are more difficult to fragment.

In this study, two retrieval bags were used. One is the Endo Catch II, which has perforations at the ring so manipulations of the urolith have to be performed delicately in order to not tear the bag at the perforations. It is recommended that when the Endo Catch II bag is used, the urolith is manipulated into the bag by direct visualisation using an endoscope to help prevent this tearing. The authors recommend a thicker laparoscopic retrieval bag which is now commercially available from Mila and does not have perforations that lead to tearing. The design of the Mila bag also allows for it to be retracted and re-deployed as necessary with no damage to the bag, allowing for greater manoeuvrability of the bag.

Rectal perforation due to transrectal manipulation of a urolith has been reported (Laverty *et al.* 1992). Transrectal palpation and manipulation should always be performed with great care but in the cases included in this study there were no complications with transrectal manipulation of the urolith. Once the urolith has been positioned into the laparoscopic retrieval bag, transrectal manipulation is restricted to the caudal 15–20 cm (estimated) of the rectum. Claes *et al.* reported that the median distance from the anus for rectal tears was 25–30 cm (Claes *et al.* 2008).

This technique required less surgical time and was less expensive than other published techniques. Reported surgical times for removal of cystic calculi are 210 min (ballistic shockwave) (Koenig *et al.* 1999), 125 min (pneumatic radial shockwave lithotripsy) (Katzman *et al.* 2016), 7 hours (electrohydraulic lithotripsy) (Reichelt and Lischer 2013), 70 min (pararectal cystotomy) (Abuja *et al.* 2010) and 59 min (parainguinal laparocystotomy) (Beard 2004). The average surgical time in this study was 68.1 min. The cost to the client for the procedure was $1000–2400 which varied across the different institutions.

Complications associated with PU for the treatment of cystic calculi have been reported (Holt and Pearson 1984; Laverty *et al.* 1992; Kilcoyne and Dechant 2014). Kilcoyne and Dechant (2014) reported a high incidence of complications following PU for treatment of urolithiasis (54.5%, 12/22) but this report overstates the risk of complications. Only four of the nine listed complications were directly related to the PU: severe haemorrhage, urethral fistula, urine scald and urethral stricture. Within those cases, the urine scald only occurred in permanent PUs and the strictures only occurred in donkeys (Kilcoyne and Dechant 2014). In this study, no complications associated with the PU were reported.

No complications were observed in this study. Care must be taken to avoid known complications associated with transrectal palpation and PU, but the authors consider the risk of these complications to be low. Additionally, the operator must expect to spend some time gaining experience with the lithotrite and retrieval bag before being comfortable employing their use. The most serious complication that the authors can perceive is if the lithotrite becomes displaced from the stone and then either tears the bag, or worse, traumatises the bladder. For this reason, it is important to rely on transrectal palpation to assure proper placement of the lithotrite against the stone as well as frequent removal of the lithotrite to flush fragments from the bag and reorient the urolith(s).

In conclusion, the reported technique for removal of cystic calculi in the standing horse results in less trauma to the bladder than techniques involving cystotomy or not involving use of a retrieval bag, the shortest mean surgical time of a standing procedure that fragments and removes uroliths, and is a safe, cost-effective alternative to other techniques.

Authors' declaration of interests

N. De Bernardis, K. Seabaugh and M. Mudge have no conflict of interest. J. Ismay has a patent on this procedure referred to as – Closed System Pneumatic Impact Lithotripsy.

Ethical animal research

The authors believe that this procedure is the best option for patients with urolithiasis. Clients were informed of the risks of the procedure and provided their consent.

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Authorship

N. De Bernardis performed most of the data analysis and interpretation (calculating average times, compiling data from different cases to summarise procedure and results, performing follow-up, etc.) and prepared the manuscript. K. Seabaugh contributed to the study design, study execution (was present for 4/11 cases), data analysis and interpretation, and preparation of the manuscript. J. Ismay contributed to the study design, study execution (was present for 6/11 cases) and preparation of the manuscript. M. Mudge contributed to the study design and study execution (was present for 1/11 cases). All authors approved the final version of the manuscript.

Manufacturers' addresses

[1]MWI Veterinary Supply, Boise, Idaho, USA.
[2]Cameron Pharmacy, St. Matthews, South Carolina, USA.
[3]Amneal Pharmaceuticals, Glasgow, Kentucky, USA.
[4]Pfizer, New York, New York, USA.
[5]Butler Schein Animal Health, Dublin, Ohio, USA.
[6]Fort Dodge Animal Health, Fort Dodge, Iowa, USA.
[7]Lloyd Laboratories, Shenandoah, Iowa, USA.
[8]Zoetis, Florham Park, New York, USA.
[9]Hospira, Inc., Lake Forest, Illinois, USA.
[10]Boehringer Ingleheim, Ridgefield, Connecticut, USA.
[11]MILA International, Kentucky, USA.
[12]Covidien, Massachusetts, USA.
[13]Henry Schein® Animal Health, Dublin, Ohio, USA.
[14]Surgilube, HR Pharmaceuticals, Inc., York, Pennsylvania, USA.
[15]Jonnesway, Taipei, Taiwan.
[16]Bute Boluses, Vedco, Saint Joseph, Missouri, USA.

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