Veterinary Research Communications (2022) 46:871–877
https://doi.org/10.1007/s11259-022-09914-7

ORIGINAL ARTICLE

Urethral Urolithiasis in Male Cattle Treated Using Pneumatic Lithotripsy

Uğur Aydın[1] · **Özgür Aksoy**[1]

Received: 27 August 2021 / Accepted: 9 March 2022 / Published online: 15 March 2022

Abstract
One of the most important problems encountered in cattle breeding is urethral urolithiasis. Urolithiasis can be treated using various methods, but they all carry risks. Thus, a continuous search is being carried out for alternatives in this field. This study aimed to treat urethral urolithiasis in male cattle using pneumatic lithotripsy, a minimally invasive method. The urethra and penile tissues of 20 male cattle of different ages and breeds were obtained from slaughterhouse materials and measured before determining the probe diameters and lengths. The study included 9 male cattle (2 Simmental hybrids, 1 Zavot hybrid, 1 Brown, and 5 Simmental), between 4 months and 2 years of age, diagnosed with urethral urolithiasis. A modified lithotripsy apparatus was used for the pneumatic disintegration of urinary stones. The localization of urinary stones in the urethra was determined by palpation and catheterization. After laying the animal in a lateral position, a lithotripsy probe of appropriate length and diameter was advanced from the external urethral orifice to the site of localization. Once the probe came into contact with the stone, a vibration of 125 bar was applied until the stone was broken. The probe was removed, and the urethral channel was washed with 0.1% iodine solution to remove the shredded urethral stones. Uncomplicated recovery was achieved in all treated cases. In conclusion, pneumatic lithotripsy provided successful results in treating urolithiasis and can be used as an alternative surgical method in cattle. Moreover, the low cost is an additional advantage to breeders.

Keywords Bovine · Pneumatic lithotripsy · Urethral obstruction · Urolithic

Introduction

Urolithiasis is a disease caused by the accumulation of protein molecules around a nucleus in the kidney, ureter, bladder, or urethra. These insoluble salts and minerals form stones that block the urinary tract (Özaydın 1996; Belknap and Pugh 2002). Besides age, sex, nutrition, and geographical causes, multiple factors, such as calculus, penile abscess, cystitis, urethral stenosis, fibrin masses, and urethral tumors, play a major role in the formation of urolithiasis. Uroliths draining into the urethra after their formation in any part of the urinary system often causes blockage at the level of the sigmoid flexure (Kılıç et al. 2004; Kılıç 2004; Parrah 2009; Eccles 2010; Makhdoomi and Gazi 2013).

Surgical approaches for treating urolithiasis include perineal urethrotomy and urethrostomy, ischial urethrotomy and urethrostomy, tube cystostomy, percutaneous tube cystostomy, and parapenile urethral penotomy (Lundvall 1988; Rakestraw et al.1995; Ewoldt et al. 2006, 2008; Muhee 2006; Parrah et al. 2011; Simpson and Streeter 2014; Ermutlu et al. 2015). Difficulty in application, postoperative risks, treatment cost, and protection of the breeding value of the animal are determinants of the preferred surgical treatment method (Ermutlu et al. 2015). Procedures including ultrasonication, extracorporeal shock waves, holmium:yttrium aluminum garnet (Ho:YAG) laser, pneumatics, and electrohydraulics have been used in human medicine since the 1970s and in the veterinary field since the 1990s for lithotripsy (Teichman et al. 1998; Miller and Stoller 2013; Maden et al. 2016). The pneumatic lithotripsy (PL) device breaks the stones with the ballistic energy generated by pneumatic pressure created when compressed air propels a bullet that hits a stainless steel probe (Elmed Medical Systems 2018).

This study aimed to present the results of the use of a PL device and probes designed for the removal of uroliths causing urethral obstructions in male cattle.

✉ Uğur Aydın
uguraydin076@hotmail.com

[1] Department of Surgery, Faculty of Veterinary Medicine, Kafkas University, Kars, Turkey

Materials and methods

Ethical approval

This study was conducted with the approval of Kafkas University Animal Experiments Local Ethics Committee (Approval no: KAU-HADYEK/2018–013) and with the consent of the cattle owners.

Study material

Cadaver materials and clinical cases

Before starting clinical applications, the penis and urethra tissues of 20 male cattle of different ages were collected from the slaughterhouse. The diameter of the urethra and its length between the archus ischiadicus and the orifice urethra externa were measured and recorded.

The clinical applications of the study were performed on 9 male cattle brought to Kafkas University Faculty of Veterinary Medicine Education, Research and Practice Animal Hospital Surgery Clinic. The animals brought to sexual maturity in different races (2 Simmental cross, 1 Zavot cross, 1 Brown, and 5 Simmental), aged between 4 months and 2 years, regardless of their adulthood, and with complaints of inability to urinate for 24–72 h, intermittent urination, or painful urination, and those diagnosed with urolithiasis were used.

Tools and equipment

A Vibrolith (Elmed Medical Systems, Turkey) lithotripsy device was used in this study (Fig. 1A). The probes of the PL device used in humans are mostly designed to be 0.8–2 mm in diameter and 38–64 cm in length. The probes used with the device were especially designed for this study with semi-rigid equal lengths (120 cm) and different diameters (2, 3, 4, and 5 mm) to suit different predetermined urethral diameters of cattle (Fig. 1B). These probes were made by Elmed Medical Systems.

Study Design

Cadaver study

The urethras of cattle of different breeds and ages were catheterized with urinary catheters of different diameters and lengths, and urethral lengths between the arcus ischiadicus and external orifice were measured and recorded.

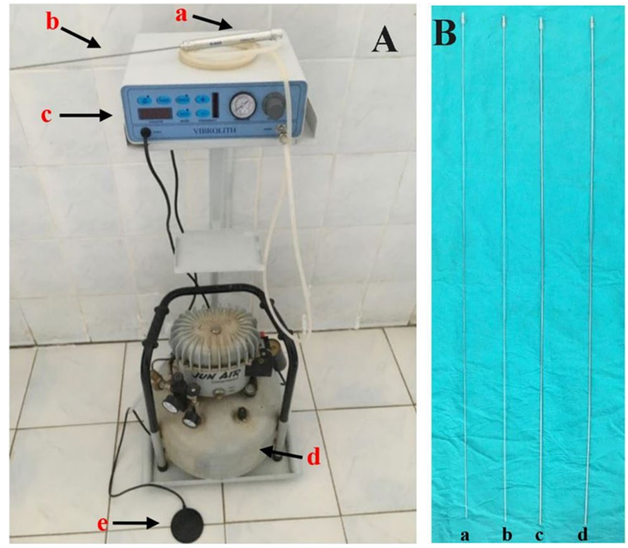

Fig. 1 **A** Ready-to-use view of the PL device, a- Elcek, b- Probe, c- Vibrolith, d- Compressed air compressor, e- Pneumatic foot pedal. **B**: Different diameter 120 cm long probes, a—2 mm, b—3 mm, c—4 mm, d—5 mm

The data obtained were used as information to design the probes used in the study.

Selection of clinical cases

Clinical examination First, anamnesis information was obtained from the animals brought to the clinic with complaints of inability to urinate or drip-like urination. In the anamnesis, information such as when the animal could not urinate or had difficulty urinating, and when the animal last drank water was recorded. In the case of pain, the last time the pain was experienced (to guide whether the bladder was intact or not) was learned from the animal owner.

Then, the presence and degree of dehydration were determined by evaluating physical findings (general appearance, skin elasticity, mucous membranes, position of the eyeball in the orbit, capillary refill time, body temperature, heart rate, and respiratory rate) within the scope of a systematic clinical examination. According to the physical examination findings, blood was taken from animals with a degree of dehydration greater than 5% for biochemical examinations (to determine urea and creatinine values) and sent to the laboratory.

In line with the laboratory examinations, the glans penis to the arcus ischiadicus, especially the flexure sigmoidea region, was palpated to determine whether a stone was obstructing the urethra and to determine its localization if present.

Following the determination of the localization of the stone, abdominocentesis was performed to determine the characteristics of the intra-abdominal fluid under ultrasound guidance. Thus, whether a uroabdomen was present was determined. Finally, the bladder was examined in detail with ultrasonography, and information was obtained about the strength of the bladder wall, whether there is urolith in the bladder, and cystitis.

No sedative or analgesic agents were used for clinical examination. Fluid treatments to be applied when deemed necessary were performed during and after the operation.

Preoperative clinical examinations were completed in approximately 30 min. Animals with diagnosed urethral urolithiasis were included in the study for lithotripsy operation.

Animals with only urethral urolithiasis or diagnosed with bladder rupture with urethral urolithiasis were included in the study for lithotripsy operation.

PL procedure

In animals with urethral urolithiasis, metamizole sodium + butylscopolamine bromide (Buscopan Compositum, Böhringer Ingelheim, USA) at a dose of 5 mL/100 kg body weight was administered primarily to achieve muscle relaxation. After placing the animal in the right lateral position, the penis was grasped out of the prepuce by hand or with long cuff pliers and held in a fixed position with a gauze by an assistant. A lubricating lidocaine gel (Cathejell Lidocaine C, Medizin zum wieder Wohlfühlen, Austria) was applied to the urethra, and a lithotripsy probe suitable for the diameter of the urethra was selected. The probe was advanced from the external orifice to where the stone was localized (Fig. 2A). Compressed air was then transmitted to the probe to break the stone in a controlled manner, which hit the stone until it was crushed into tiny pieces. The movement of the probe in the forward direction from where it was inserted before the lithotripsy procedure confirmed that the stone was completely broken. Once the stone was broken, the probe was removed, and some pieces of the stone were extruded with the first urine output (Fig. 2B). A 6F urinary catheter was then introduced into the urethra (Fig. 2C), and the urethra was lavaged using a 0.1% iodine solution (Dermosept, Aktas Cleaning and Cosmetic Ltd., Istanbul, Turkey) (Fig. 2D). Spontaneous urination by the animal confirmed that the stone-induced blockage problem was resolved (Fig. 2E and F).

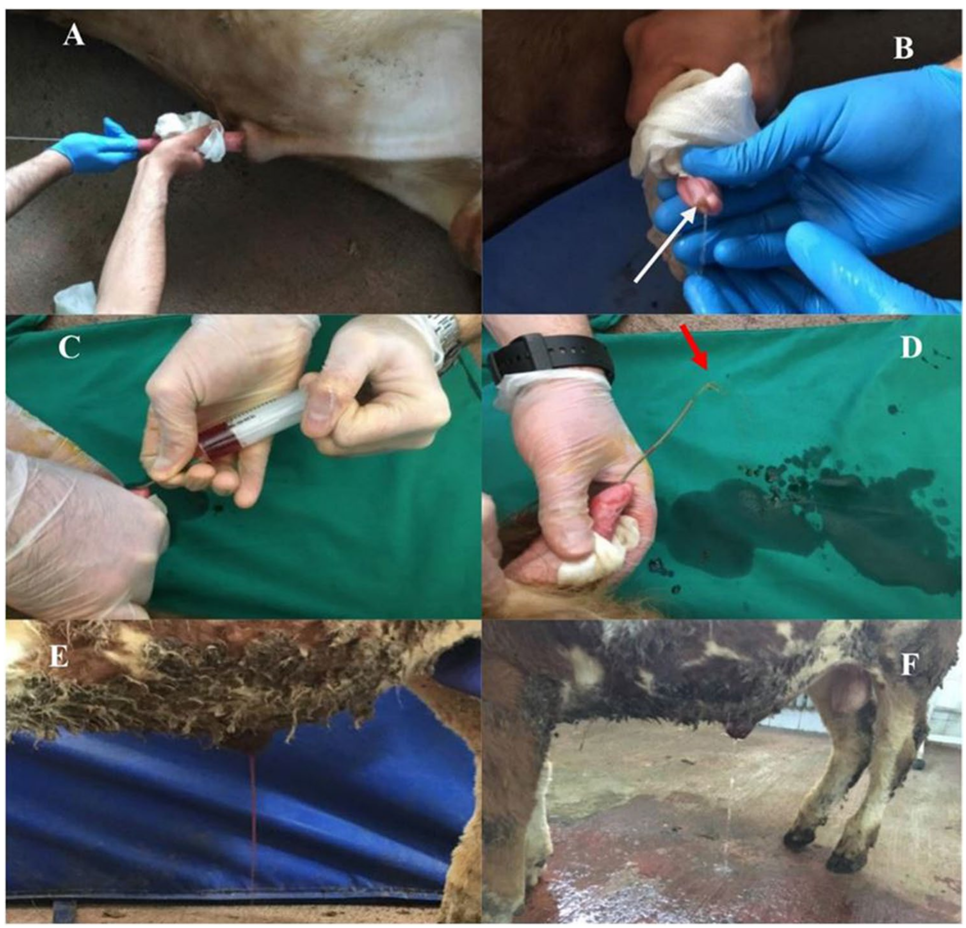

Fig. 2 Lithotripsy Procedure. **A** Inserting the probe from the external urethral orifice until the stone is reached, **B** Stone excretion with urine output after fracture (Arrow), **C** Pressure lavage of the urethra with an antiseptic solution, **D** Backflow of the fluid given for retrograde urethral lavage (Arrow). **E, F** Urine flow when the animal is raised to its feet (bloody-**E**, normal-**F**)

Postoperative care

In the postoperative period, all animals were given intravenous 0.9% NaCl (Neofleks, TURKTIPSAN Health Tourism Education and Trade Inc., Akyurt/Ankara, Turkey) in amounts determined according to the degree of dehydration present and kept under surveillance until urination occurred. Penicillin–streptomycin, 4 mL/100 kg body weight intramuscular (IM) injection for 5 days (Redipen, Sanovel, Turkey), and gentamicin sulfate, 8 mL/100 kg body weight IM for 3 days (Gentavet, Vetaş, Turkey), were administered as antibiotic therapy. In addition, methenamine + methenamine anhydromethylenecitrate 50 mg/kg (Purinol, Recordati Ilac San. Tic., Turkey) as a urethral antiseptic and vitamin C 20 mL/day IM (İnjaco I-C, Ceva Animal Health Co., Turkey) for 5 days, and furosemide 0.5–1 mg/kg IM (Diüril, Vetaş, Turkey) as a loop diuretic and Buscopan (0.2 mg of butylscopolamine bromide and 25 mg of metamizole/kg iv-im) for 3 days were also administered.

Chemical analysis of the stones

The chemical structures of the stones were analyzed by x-ray diffraction at Turkey General Directorate of Mineral Research and Exploration.

Results

The cadaver cattle urethras measured 110–120 cm in length and 3–5 mm in diameter. Based on this information, probes with a length of 120 cm and diameters of 2, 3, 4, and 5 mm were determined to be suitable for lithotripsy.

In all 9 animals with urethral urolithiasis included in the study, the general symptoms were inability to urinate, pain, anorexia, restlessness, and intermittent urination. The animals had a taut posture. The stones were localized at the sigmoidea level of the flexura in the postscrotal region in all cases.

The mean physical examination findings of the animals were as follows: The respiratory rate per minute, pulse rate and rectal temperature recorded as 43.22, 96.55, and 38.14℃, respectively. In addition, the mean urea concentration was 94.94 mg/dL and the serum creatinine concentration was 10.36 mg/dL in 3 patients who were severely dehydrated.

Fluid was taken from each animal by abdominocentesis, and their physical characteristics were examined. Whether the abdominocentesis fluid sample was urine was confirmed using urine strips (Urinalysis Reagent Strips, Laboquick, Turkey).

In 8 animals, the stones were divided into tiny pieces (Fig. 3a) in the urethra and easily expelled by lavage, except in 1 animal, in which case the stone was quite large (larger than 1 cm) and was thrown out by dividing into 3 large pieces (Fig. 3b).

The chemical analysis confirmed that all of the stones were struvite.

No damage to the urethra, injury, or bleeding was observed during fracture and removal of stones. However, in two cases, the urine was slightly bloody when the stone was broken and the animal initially urinated after standing up (Fig. 2E). During the period under surveillance (2 h postoperatively), the urine was completely clear by the second and third urination for these two animals (Fig. 2F).

All of the 9 cases included in the study were followed up for one postoperative year and they were followed up by telephone or patient visits. No adverse events were encountered.

Discussion

Urinary system diseases in male cattle are mostly cystitis, urinary bladder rupture, urethral narrowing and obstruction, urethritis, and urethral fistulas (Görgül et al. 2012). Of these, urinary bladder ruptures and urethral obstructions are most commonly encountered (Kılıç et al. 2004; Öztürk et al. 2007). Urolithiasis has been shown to be the primary cause of these maladies (Radostits et al. 2000; Kılıç et al. 2004;

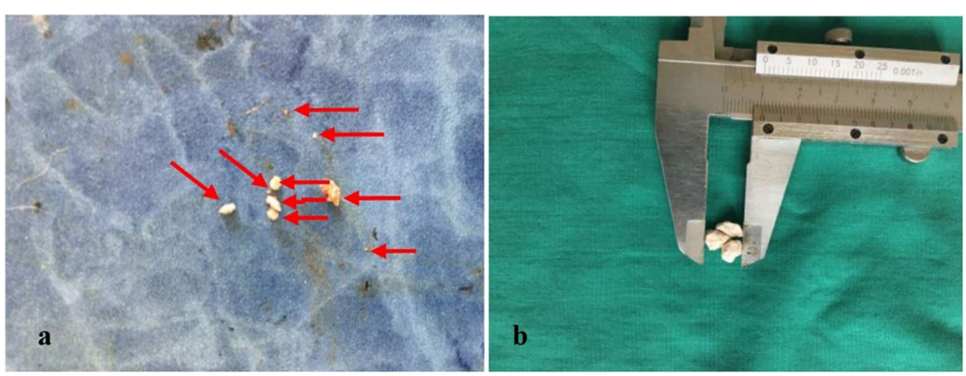

Fig. 3 **a** Image of urinary stones broken into tiny pieces (Arrows). **b** Image of a urinary stone that was removed in 3 pieces after it was broken in a case

Öztürk et al. 2007; Görgül et al. 2012). Urethral obstruction due to urinary system stones was observed in all cases included in our study. In cases brought to the clinic complaints of inability to urinate, first of all, the urethra should be examined and any obstruction should be removed. Otherwise, treatment procedures (fluid supplementation, diuretic use, etc.) without removing the obstruction may cause different urinary system problems.

Urinary stones may be localized anywhere in the urinary system from the renal pelvis to the glans penis. However, it is known that in male cattle the urolith causes obstruction in the urethra, especially in the sigmoid flexure, due to the length of the urethra and the presence of the sigmoid flexure. Obstructive urinary calculi are usually irregular in size and diameter, and most commonly located at the insertion point of the musculus retractor penis muscle distal to the sigmoid flexure (Gera and Nigam 1979; Loretti et al. 2003; Ewoldt et al. 2008). Urinary stones were detected in the postscrotal region of the urethra and the flexure sigmoidea in all animals in this study. The diameter of the urinary stones varied between 1.2 cm in 1 animal and between 3 and 8 mm in 11 animals. These findings showed that especially palpation of the flexure sigmoidea region was of great importance, considering the size of the stones, as well as other examinations, in animals with the complaint of inability to urinate.

In cattle, obstructive uroliths may be of different sizes, shapes, colors, and structures. The formation of these stones can be influenced by excessive mineral intake, hypovitaminosis A, hypervitaminosis D, calcium/phosphorus imbalance in the diet, insufficient water intake, urine pH, and unbalanced pelleted feed:roughage ratio. In addition, fibrin tangles caused by cystitis, pyelonephritis, and urethritis can be considered among the causes of uroliths (Özmen 2004; Kılıç et al. 2004; Parrah 2009; Eccles 2010; Makhdoomi and Gazi 2013; Kamiloğlu and Kılıçoğlu 2017). Uroliths are composed of magnesium ammonium phosphate (struvite), calcium phosphate, calcium carbonate, calcium oxalate, uric acid, hippuric acid, and tyrosine. Among these, struvite, calcium oxalate, and calcium carbonate stones have been reported the most (Parrah 2009; Makhdoomi and Gazi 2013). Although the stones in the study were of different sizes, shapes, and colors in four cases, the chemical analysis revealed that all of them were struvite stones. In accordance with this information, the animal owners were informed that a balanced adjustment of the roughage:pelleted feed and vitamin:mineral ratio in the feed and the amount of water provided to the animals would greatly reduce stone formation and prevent the possibility of recurrence in the treated animals. This encounter was associated with recurrence in the postoperative period, and hence the animal owners were informed.

Urolithiasis cases caused by uroliths have been encountered geographically almost all over the world. Seasonally, the risk of urolithiasis increases with the increase in crystallization as a result of excessive intake of grain feeds, insufficient vitamin A intake, not consuming too much water, especially in the winter months, and dehydration due to excessive sweating in the summer months. Although urolithiasis is encountered in all age groups, it is more common in cattle under 2 years of age, especially due to protein-weighted one-way feeding. However, calves up to 6 months old and castrated cattle are more susceptible to urolithiasis (Parrah 2009; Muhee 2006; Fazili and Ansari 2007). In all the animals in this study, urethral obstruction was formed due to urinary system stones. The animals included in this study were aged between 4 months and 2 years, similar to previous studies. Anamnesis information revealed that the animals were considered for breeding. Thus, for rapid growth and development during the calf period, the animals were fed intensively with pelleted feed, while the grazing period and the rough food quantity were low. Also, water intake was reduced in cold weather. Urethral obstructions after calculus formation or urinary bladder ruptures due to obstruction were more frequently encountered in autumn, winter, and spring months during intensive feeding periods. The formation of urinary system stones causing urethral obstructions can be prevented by adjusting the ratio of roughage:pelleted feed, tracking the decreasing water intake of animals, especially in winter, keeping water available constantly, and balancing the vitamin:mineral ratio in their food.

Obstructive urolithiasis treatment options include urethrotomy, urethrostomy, parapenile urethral penotomy, tube cystotomy, and wig tube cystotomy. Many of these methods have the disadvantages of re-constriction of the urethra or complete obstruction (Özaydın 1996; Ewoldt et al. 2006; Muhee 2006; Parrah et al. 2011; Simpson and Streeter 2014; Ermutlu et al. 2015). Minimally invasive methods, such as basket catheterization, have been developed to overcome these disadvantages; although positive results have been obtained using basket catheterization, the disadvantage of this method was the inadequate removal of localized stones in the postscrotal region (Kılıç et al. 2003). Nowadays, lithotripsy has come to the forefront in an effort to overcome these disadvantages. Various methods, such as extracorporeal shock wave lithotripsy (ESWL), electrohydraulic lithotripsy (EHL), ultrasonic lithotripsy (USL), PL, and Ho:YAG laser lithotripsy, have been used in human and animal urology procedures (Miller and Stoller 2013; Maden et al. 2016). In the present study, both slaughterhouse and clinical trials were planned for modified PL and a successful application option was created.

ESWL has been used successfully in treating ureteral and kidney stones in dogs. However, the use of ESWL in cats is a minimally invasive treatment, which may be insufficient for the fracture of cystine stones and calcium oxalate stones and may result in postoperative renal destruction (Adams and Senior 1999; Turgut et al. 2007; Verwilghen et al. 2008; Maden et al. 2016). The EHL method was developed to prevent the urethral mucosa damage. However, some studies reported that complications, such as superficial mucosal damage and hematuria, could occur (Maden et al. 2016). The EHL has been used to break urinary bladder stones in dogs, but this technique can cause damage to the urethra due to the high energy supply to the area. A comparison of USL and PL in a study on rats to treat urinary bladder stones found that USL caused hemorrhage and edema in the urinary bladder, but no complications were encountered with PL (Adams and Senior 1999; Adams and Lulich 2006; Diri et al. 2012). A Ho:YAG laser lithotripsy device has reportedly been used in horses, humans, pigs, dogs, and ruminants (Adams and Lulich 2006). As laser lithotripsy has a photothermal effect, a risk of prolonged contact damaging the urethral mucosa or urinary bladder exists (Menendez and Fitch 2012; Maden et al. 2016). Despite the advantages of ESWL, EHL, USL, and Ho:YAG laser lithotripsy, the devices are expensive, the accessibility to the devices is low, the fracture of large stones is difficult, and ESWL is inefficient in the case of large animals (Adams et al. 2008). In addition, some procedures are limited to large animals due to the large equipment size (EHL) (Adams and Senior 1999; Adams and Lulich 2006). However, the PL approach to urethral stones with reuse of the probe, low cost, safety, and practical advantages has increased the preferability of this method (Miller and Stoller 2013; Maden et al. 2016). PL is widely used in humans for the disintegration of urethra and urinary bladder stones. In the veterinary field, it was first used to break ureteral stones in pigs and dogs. Compared with other lithotripsy methods, mucosal hemorrhage and other complications have been reported to be less with this method, and it has been successfully used in cases of urethral obstruction (Maden et al. 2016). In this study, the urinary tract was opened by breaking the stones in all animals. In 10 of the 12 animals, the first urination was within the physiological limits, without any problem. In only two animals, the first urination was slightly bloody because of the slight damage to the urethral mucosa during the fracture due to the irregular shape of the stone. However, the urine became clear in the subsequent urinations.

The probes of the PL device used in humans are mostly designed to be 0.8–2 mm in diameter and 38–64 cm in length (Elmed Medical Systems 2018). In this study, a private company modified and produced a semi-rigid device to be 120-cm long and 2–5 mm in diameter to break the urethral stones in male cattle. This device, used for the first time for fracturing urethral stones in cattle, was successfully used in the fragmentation of the stones causing urethral obstruction in all the animals. The advantages of PL included its ease of use and high rate of shredding urethral stones. No postoperative complications were encountered in the animals used in this study. It was extremely painless and easy to use with the application of lidocaine lubricating gel during entry of the semi-rigid probe into the urethra. No recurrence and no urethral damage was reported. The device could be used by clinician veterinarians without requiring much experience.

This study had some disadvantages. It was only possible to advance the device to the stone blindly. The modified device could only be used in the treatment of urethral stones in cattle, and it had no apparatus for urethral lavage. The device can be made more efficient by employing a camera system to see the stone, thereby developing a flexible probe to break the stones in cattle, and by adding lavage capabilities to clean the urethra during lithotripsy.

Conclusions

PL can be used successfully to treat urethral stones in cattle, protecting their breeding values and preventing economic loss. In addition, the equipment and procedure are easy to use and apply in field conditions.

Author contribution UA and ÖA planned and designed the research. UA followed the clinical process. UA and ÖA analyzed statistical data. UA and ÖA discussed the results and contributed to the final manuscript.

Funding This work is supported by the Kafkas University Scientific Research Projects Coordinator, Kars, Turkey (Project No: 2018-TS-45).

Data availability statement All data generated or analyzed during this study are included in this published article [and supplementary information files]. All other data supporting the findings of this study are available from the corresponding author on request.

Declarations

Ethics approval All institutional and national guidelines regarding the care and use of patients were followed.

Conflict of interest The authors declare no competing interests.

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