Review

https://doi.org/10.47748/tjvr.1698544

TJVR 2025; 9 (2): 151-156

Turkish Journal of Veterinary Research

https://dergipark.org.tr/tr/pub/tjvr

e-ISSN: 2602-3695

Extracorporeal shock wave lithotripsy in small animal clinical practice

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Received: 13.05.2025 Accepted: 22.06.2025

ABSTRACT

Nowadays, medical treatment and/or surgical procedures in the management of urolithiasis have increasingly been replaced by various minimally invasive techniques. One such method is Extracorporeal Shock Wave Lithotripsy (ESWL), which works by focusing shock waves generated from an energy source onto the urolith to fragment it. It is used specifically for breaking stones that are localized in a fixed position. ESWL has rapidly gained ground worldwide as a treatment option for urolithiasis. It has been used for the fragmentation of nephroliths, ureteroliths, and cystoliths in dogs, and ureteroliths and cystoliths in cats with high success rates in small animal veterinary practice for approximately 25 years. In some dogs, it is also known to be used for reducing the size of bladder stones. Since ESWL is a relatively new treatment modality in the field of veterinary medicine in Turkey, this review aims to evaluate the usability and effectiveness of ESWL in small animal clinical practice.

Keywords: *ESWL, Urolith, Nephrolith, Cat, Dog*

INTRODUCTION

Urolithiasis refers to the formation of structures resulting from the crystallization and precipitation of mineral components in the urine, forming solid accumulations known as stones (Putchakayala and Haritha, 2024). An increase in the saturation of urine with crystalloids, depending on factors such as the volume of urinary crystals, excretion of crystals from the kidneys, urine concentration, urine pH, the presence of substances promoting urolith formation, or the absence of inhibitors, predisposes to urolith formation (Defarges et al., 2020).

Urolithiasis can cause significant clinical morbidity and mortality in cats and dogs, as it can occur in both the upper and lower urinary tract (Loan and Dao, 2025). Urolithiasis is also considered a multifactorial disease, and understanding the composition of uroliths and identifying the causes of their formation is of great importance, especially for treatment and prevention strategies (Gomes et al., 2021). In cats and dogs, there are various types of stones such as cystine, oxalate, purine, silicate, and struvite, which may vary depending on factors like breed, sex, and age (Table 1) (Defarges et al., 2020).

Calcium oxalate uroliths account for 90% of nephroliths and ureteroliths in cats and are also the most common type of upper urinary tract stones in dogs. In addition, struvite ureteroliths and nephroliths are also quite common in both cats and dogs (Cléroux, 2018). Taking into consideration various factors such as the location, size, chemical composition of the stone, and renal fluid retention, the appropriate treatment method is determined as medical management, surgical intervention, or a combination of both (Pearle et al., 2014). Although urolithiasis in dogs and cats has been treated surgically for many years, with advances in technology, minimally invasive procedures have

Table 1. Associations between stone type and their characteristics in dogs and cats (Defarges et al., 2020).

	Dog			Cat		
	Breed	**Sex**	**Age**	**Breed**	**Sex**	**Age**
Cystine	English Bulldog, Newfoundland, Dachshund, Irish Terrier, Basset Hound, Bullmastiff, Rottweiler, Mastiff, Australian Cattle Dog, Australian Shepherd, Chihuahua, Basenji, Scottish Deerhound, Staffordshire Terrier, Pitbull Terrier, Welsh Corgi, Miniature Pinscher, Silky Terrier, Bichon Frise, Yorkshire Terrier, Dalmatian, Borzoi, Shetland Sheepdog, Doberman, Border Collie.	It is much more common in male dogs (except Newfoundlands).	Young and middle-aged dogs (3–8 years), with the exception of Newfoundlands.	It is very rare in cats.	Females are equal to males.	At any age, on approximately 3–5 years and older.
Oxalate	It can be seen in all breeds; however, the risk is increased in Miniature Schnauzers, Bichon Frises, Lhasa Apsos, Yorkshire Terriers, Miniature Poodles, Shih Tzus, and other small breed dogs. The predisposition in small breeds may be associated with lower urine volume, less frequent urination, and possibly higher mineral concentrations compared to large breeds.	It is more common in male dogs; the exception is the Miniature Schnauzer.	There is no age difference (generally older than those with struvite stones).	Persian and Himalayan cats	More common in neutered male cats than in females.	Over 7 years but under 10 years old.
Purine	Black Russian Terriers, Shih Tzus, Miniature Schnauzers, Yorkshire Terriers, Dalmatians, English Bulldogs.	Pure urates are more common in males.	Variable (any age in Dalmatians, but typically 1–4 years; 3–6 years in other breeds)	Siamese, Birman, Egyptian Mau	There is no sex predisposition in cats.	The average age is 6.3 ± 0.17 years.
Silicate	German Shepherds, Old English Sheepdogs, Miniature Schnauzers, Shih Tzus, Lhasa Apsos, Yorkshire Terriers, Pekingese, Labrador Retrievers, Golden Retrievers, Cocker Spaniels, English Bulldogs, Bichon Frises, Rottweilers, and mixed breeds.	Much more common in male dogs.	Middle-aged dogs	There is no breed-specific predisposition.	There is no sex predisposition.	There is no age-related predisposition.
Struvite	Any breed Increased risk in Miniature Schnauzers, Bichon Frises, Shih Tzus, Lhasa Apsos, Yorkshire Terriers, Miniature Poodles (and other small breed dogs). The predisposition in small breeds may be associated with lower urine volume, less frequent urination, and possibly higher urinary mineral concentrations compared to large breeds.	More common in female dogs.	There is no age predisposition (middle-aged but generally younger than those with oxalate stones). Stones seen in dogs under one year of age which are often composed of struvite.	Any breed Himalayan, Persian, domestic cats	There is no sex distinction; however, it may be slightly more common in females over 2 years of age.	There is no age predisposition, but it typically occurs in cats over 6 years of age.

become common practice. It has therefore become increasingly important for clinicians to evaluate alternatives beyond traditional surgery, especially as not all methods are suitable for every case (Lulich et al., 2016). Non-operative minimally invasive procedures include urohydropropulsion, intracorporeal lithotripsy, ESWL, basket retrieval of stones under cystoscopic guidance, percutaneous cystolithotomy (PCCL), and laparoscopic-assisted cystotomy (Defarges et al., 2020).

ESWL refers to the fragmentation of stones using high-energy shock waves generated outside the body, which are reflected through intervening tissue to the stone (Adams and Senior, 1999; Cui et al., 2015). Due to its minimally invasive nature and low anesthesia requirements, ESWL has become an important alternative to surgery in the treatment of urinary tract stone disease (Turkay et al., 2018).

In this review, the effectiveness, applicability and treatment response rates of the ESWL method used in the management of urolithiasis cases are evaluated in light of scientific data, taking into consideration its complications and potential adverse effects in veterinary clinical practice in Turkey.

1. History of extracorporeal shock wave lithotripsy

The idea of using shock waves medically first emerged in the 1950s. In 1974, a German aircraft company, Dornier, while investigating the damage caused by rain droplets on aircraft wings, discovered that the power of shock waves could break solid objects and began research into their potential use in treating stones in the human body. After successful animal experiments, the first human trial using ESWL was conducted on February 7, 1980. Christian Chaussy treated a renal pelvis stone using the first prototype ESWL device (HM1 = Human Model 1) produced by Dornier. Subsequently, the more effective HM2 model was developed in 1982. As a result, ESWL quickly spread worldwide and is now used in the treatment of urinary system stone disease (Eisenberger et al., 1977; Chaussy et al., 1980; Chaussy et al., 1982; Fuchs et al., 1985; Özgök et al., 1993; Sağlam and Adsan, 1998; Soller, 2004; Bedir et al., 2011).

2. Mechanism of extracorporeal shock wave lithotripsy

The basic principle of ESWL is the focusing of shock waves, produced outside the body, onto a specific target inside the body through a conductive medium (water) (Bedir et al., 2011). The targeted uroliths are fragmented into smaller pieces thousands of times by shock waves of varying energy levels, allowing them to reach the bladder and be naturally excreted from the body (Milligan and Berent, 2019). Shock waves are high-amplitude acoustic waves that are produced by electrohydraulic, electromagnetic, or piezoelectric energy sources (Berent and Adams, 2015). The similar densities of water and the human body allow for the easy transmission of sound waves from the water medium to the body, while the difference in density when transitioning from water to stone leads to the fragmentation of the stone (Bedir et al., 2011).

Table 2. Characteristics of extracorporeal lithotripters used in small animal medicine (Lane, 2004).

Model	Source	Focus	Conductor	Imaging	Focal Area	Peak Pressure
HM-3	EHL	Ellipsoid	Water bath	Radiography	15 x 90 mm	1300 bar
Modulith	Electromagnetic	Parabolic	Water cushion	Rad/US	6 x 30 mm	1000 bar
MFL-5000	EHL	Ellipsoid	Water cushion	Rad/US	10 x 40 mm	1000 bar
Piezolith 2500	Piezoelectric	Concave Reflector	Water cushion	Rad/US	1.5 x 11 mm	1200 bar
Lithostar II	Electromagnetic	Acoustic Lens	Water cushion	Rad/US	6 x 80 mm	500-800 bar

Abbreviations: EHL, electrohydraulic; Rad/US, both radiographic (fluoroscopic) and ultrasonographic imaging.

Although there are different types of lithotripters, they all rely on the same acoustic physical principles: shock waves generated outside the body, consisting of a positive peak followed by a negative suction wave, which are transmitted from the body to fragment the stones (Weizer et al., 2005). Lithotripters consist of four components: an energy source that generates shock waves (electrohydraulic, electromagnetic, piezoelectric), a device that focuses the shock waves to a focal point (ellipsoid reflector, acoustic lens), an intermediary medium (bath, water cushion, gel), and a stone localization system (fluoroscopy, ultrasound) (Table 2) (Bedir et al., 2011).

There is no consensus on the number of shock waves given in veterinary medicine; however, it is commonly accepted that 1,000 to 3,500 shocks are used for urolith fragmentation (Berent and Adams, 2015; Cléroux, 2018). In the original ESWL methods, patients were partially immersed in water (Chaussy et al., 1980; Chaussy et al., 1982; Adams and Senior, 1999), while newer lithotripters prefer "dry" techniques, where the patient is positioned on a plastic bed, and shock waves are transmitted to the patient through a liquid-filled cushion (Chow and Streem, 2000; Auge and Preminger, 2002; Lane, 2004). Although dry lithotripters are less effective compared to the "gold standard" water bath model due to their smaller focal area and lower peak pressure, the narrow focusing area ensures precise targeting of uroliths while minimizing shock wave damage to surrounding tissues (Chow and Streem, 2000; Lane, 2004).

3. Extracorporeal shock wave lithotripsy application method

Before applying ESWL, a comprehensive diagnostic evaluation, including complete blood count, serum chemistry profile, urine analysis, urine culture, coagulation profile, abdominal radiography, and ultrasound, is required (Berent and Adams, 2015). ESWL requires general anesthesia and shaving of the fur to ensure proper positioning of the patient, limit patient movement, and establish a proper connection with the lithotripter head (Cléroux, 2018). To achieve accurate targeting and treatment with ESWL, the urolith must be properly detected using fluoroscopy, ultrasonography, or both, and the patient should be positioned so that the urolith is placed at the focal point with the help of the integrated targeting system of the lithotripter (Berent and Adams, 2015). Once the patient is anesthetized and the urolith is positioned at the treatment focal point, shock waves are applied to fragment the stone. In this process, voltage stepping, which starts with low voltage settings and gradually increases throughout the treatment, is a method that allows more effective fragmentation of uroliths compared to fixed voltage usage (e.g., 18 kV) (Zhou et al., 2004). Additionally, the voltage stepping method increases the tolerability of ESWL, allowing the use of lighter anesthesia levels (Lingeman, 2002).

4. Patient selection for extracorporeal shock wave lithotripsy

In cats and dogs, ESWL can be applied if there are symptoms such as ureteral obstruction due to ureteroliths (ureteroliths in dogs, distal ureteroliths in cats), pain, or recurrent infections (Defarges et al., 2020). Although effective in dogs, ESWL is rarely preferred for the treatment of ureterolithiasis in cats, as the high obstruction risk in small ureters and the resistance of calcium oxalate stones to fragmentation suggest that cats are not suitable candidates for this method (De Carvalho, 2023). In patient selection for ESWL, specific criteria exist for nephroliths in dogs; if symptoms such as hydronephrosis, recurrent infection, pain, or worsening chronic kidney failure are present, ESWL can be performed alone for stones smaller than 10 mm, ureteral stented ESWL or percutaneous nephrolithotomy (PCNL) for stones between 10-25 mm, and PCNL may be preferred for stones larger than 25 mm (Defarges et al., 2020). ESWL is contraindicated in cases of uncontrolled urinary tract infections, bleeding disorders, anatomical obstructions distal to the ureterolith, and in pregnant cats (Cléroux, 2018; Milligan and Berent, 2019).

5. Success rates in extracorporeal shock wave lithotripsy

The success rate of ESWL depends on the type of lithotripter, the size, location, and composition of the stone, as well as the applied treatment (Berent and Adams, 2015; Cléroux, 2018). ESWL treatment has been reported to be successful in approximately 85% of cases in dogs with calcium-containing nephroliths and ureteroliths (Defarges et al., 2020).

The fragmentation of ureteroliths by lithotripsy is more challenging than nephroliths due to their smaller size and the surrounding tissues, making clear visualization and accurate focusing more difficult (Lane, 2004). During lithotripsy, the adhesion of ureterolith fragments to the ureteral mucosa can prevent the stone from moving away from its original location, reducing the effectiveness of subsequent shock waves. The limited movement and reverberation of the shock waves within the stone may also restrict the fragmentation effect in the closed area of the ureter (Adams and Senior, 1999; Lingeman, 2002).

In one dog, ESWL was applied with the concurrent placement of a ureteral stent for a 1.5 cm calcium oxalate nephrolith in the kidney, but the accumulation of stone fragments led to ureteral obstruction (Petrovsky et al., 2019). ESWL is considered safe and tolerable for kidney treatment in dogs (Defarges et al., 2020). In a study involving 32 dogs with kidney or ureteral stones, although 30% of the dogs required multiple ESWL treatments, a success rate of 90% was achieved (Adams and Senior, 1999). It has been reported that in 90% of dogs, nephroliths were successfully fragmented; however, 30% of dogs required multiple treatments when an older model dry unit was used, and 50% required multiple treatments (Defarges et al., 2020). In a case report, after the application of ESWL in a Golden Retriever, two calcium oxalate ureteroliths and one nephrolith were fragmented and their sizes reduced, with these fragments completely cleared within 2 months, leaving the dog free of uroliths (Bailey and Burk, 1995).Although ESWL has been used to treat several nephrolith and/or ureterolith cases in cats, it is not a preferred treatment method in this species due to the high risk of ureteral obstruction post-ESWL, as a result of small ureters and the size of the stone fragments produced (Berent and Adams, 2015; Cléroux, 2018).

The effects of dry lithotripsy on the kidneys were examined in four healthy cats, and no significant differences were found in ultrasonographic images or glomerular filtration rate measurements 24 hours to 14 days after treatment (Gonzales et al., 2002). In a study evaluating ESWL for ureterolithiasis treatment in five cats, only one cat had complete stone resolution, two cats showed partial fragmentation but the fragments did not pass through the ureter; according to the authors' experience, two cats had successful stone passage, and the overall success rate was reported to be approximately 30% (Defarges et al., 2020).

ESWL is generally not preferred for bladder stones due to their movable structures, which easily move away from the shock waves, preventing effective reduction. However, it may be used in combination with dissolution or hydropropulsion to reduce the size of cystoliths (Loske et al., 1996; Lane, 2004).

6. Complications of extracorporeal shock wave lithotripsy

Shock wave lithotripsy can cause traumatic effects on renal tissue, leading to complications such as renal edema, renal or perirenal hemorrhage, vasoconstriction, tubular damage, intrarenal scarring, and kidney failure (Newman et al., 1987; Delius et al., 1988; Karlsen et al., 1990; Rassweiler et al., 1993; Lane, 2004). Similar to the complications seen in human medicine, in dogs, complications such as cutaneous bruising, renal hematoma, hematuria, arrhythmias, pancreatitis, and ureteral obstruction may develop (Cléroux, 2018). Pancreatitis is a rare complication encountered in dogs during the treatment of right nephroliths due to the proximity of the right kidney to the right lobe of the pancreas (Berent and Adams, 2015). In a study of 14 dogs examined within one day after lithotripsy, ultrasonographic imaging revealed the displacement of nephrolith fragments, ureterectasia, retroperitoneal fluid accumulation, and subcapsular hematoma. However, no changes were observed in the echogenicity or structure of the kidneys (Siems et al., 1999).

CONCLUSION

In some cats and dogs diagnosed with chronic kidney disease, diagnostic procedures have highlighted that the disease originates from nephroliths. We believe that, if the availability of ESWL treatment, which has been used for many years in humans and in veterinary clinical practice for over 25 years, is ensured in our country, positive outcomes could be achieved in patients with uroliths and nephroliths. Further investigation into the complications and side effects of ESWL in cats and dogs could contribute to routine clinical practices.

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ACKNOWLEDGMENTS

Author contributions: GA, DZT, MEO, and BD reviewed the literature on the topic, and all of them contributed to the drafting and revision of the manuscript. GA: Gülce Ayaş, DZT: Deniz Zeynep Telci, MEO: Mehmet Erman Or, BD: Banu Dokuzeylül.

Financial Disclosure: The authors declared that this study has received no financial support.

Conflict of Interests: The authors declared that there is no conflict of interests.

Additional information: All authors have read and agreed to the published version of the manuscript Correspondence and requests for materials should be addressed to GA.

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