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URINARY LITHIASIS AND EXTRACORPOREAL SHOCK WAVE LITHOTRIPSY: NEW APPROACHMENTS

FINAL PROJECT TO QUALIFY FOR THE TITLE OF "DEGREE IN MEDICINE"

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Dedicated to all people who suffer from or have suffered from urinary lithiasis.

ABSTRACT

Background: While ESWL is generally considered safe and effective, new methods are being created as result of continuous lithotripsy research to enhance the procedure's results.

Objective: Conduct a complete and structured analysis of the most current extracorporeal lithotripsy systems in the management of kidney stones, and collect and evaluate the complications associated with using conventional ones.

Methods: We carried out a systematic review of studies focusing on the complications associated with using conventional extracorporeal lithotripsy systems, and a second review about the most current extracorporeal lithotripsy systems, in the management of kidney stones. The bibliographic search is done through Pubmed and Pubmed Center. Based on 2574 records in total, the tittle and summary of each record are examined according to the criteria, and whether they meet the selection criteria is analysed.

Results: A total of 67 articles are included, of which 24 deal with the study of current extracorporeal lithotripsy systems and 43 on the study of complications associated with using conventional extracorporeal lithotripsy systems.

Conclusions: There are some discrepancies in the therapy safety and efficacy of ESWL. Consequently, advancements in ultrasound (US) technology must being developed, like ultrasonic propulsion and burst wave lithotripsy (BWL). Another non-invasive option that is emerging in recent years is acoustic trapping and vortex beams. In clinical and preclinical testing, these innovative, non-invasive uses have yielded encouraging outcomes.

Keywords: acoustic, hunting, vortex, ultrasonics, complication, lithotripsy, urolithiasis

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1. INTRODUCTION

1.1 Urolithiasis

1.1.1 Epidemiological Description

Nephrolithiasis is a medical condition characterized by high prevalence all over the world, 1 in 10 people will experience kidney stone illness at least once in their lifetime (1). Furthermore, urinary stones are estimated to reappear up to 50% of the time (2).

The length of hospital stays for patients with urolithiasis has reduced and therapy is now provided in an outpatient environment. Despite that, expenditures are still rising as kidney stones are becoming more common (3).

According to the population affected, the highest incidence is between 40 and 60 years old, without a clear gender difference (4). Although the highest rates have been observed in some Asian nations like Saudi Arabia (20.1%), the western hemisphere appears to have a larger chance of developing urolithiasis in adults (5-9% in Europe, 12% in Canada, and 13-15% in the USA) than the eastern hemisphere (1-5%) (5). More than 80% of kidney stones in Western nations are formed of calcium oxalate and, to a lesser extent, calcium phosphate. Additionally, during the past few decades, the percentage of stones added to Randall's plaques has grown. Randall's plaque is an interstitial apatite deposit that become overgrown with clinically significant CaOx stones (6).

1.1.2 Clinic

Many people develop kidney stones, which go unnoticed and are only accidentally discovered. Some people may have a mild discomfort close to their kidneys without diagnosing it as a kidney stone. Until they block the renal pelvis or pass through the ureter, kidney stones are frequently overlooked (7).

However, patients commonly have the classic reno-ureteral colic and less frequently loin pain; other symptoms may include gross haematuria, vomiting, and occasionally fever. It should be underlined that children above the age of 10 experience normal renal colic symptoms. Symptoms including appetite loss, diarrhoea, vomiting, nervousness, and unexplained fever are more common in younger people (8).

Discomfort is localized to the flank if the stone blocks the uretero-pelvic junction; when the stone descends the ureter, the pain shifts anteriorly and downward. Dysuria and frequent urination are symptoms of stones at the uretero-vesicular junction that are frequently misinterpreted for infections. Colic is unaffected by body mobility or location (9).

Uro-sepsis, persistent pain, approaching acute renal failure, blockage in a single or transplanted kidney, and bilateral obstructing stones are some of the symptoms that call for immediate treatment (10).

1.1.3 Risk factors and recurrence

Firstly, a low urine volume induced by insufficient fluid consumption or excessive fluid loss is one of the most important risk factors for kidney stone formation. Drinking enough water promotes urine dilution, which lowers the renal intratubular transit time and lowers the concentration of lithogenic ingredients, facilitating the evacuation of crystals (2). The most significant risk factor for calcium stone production is hypercalciuria, while other, less common abnormalities including hyperoxaluria and cystinuria are also highlighted (11).

Despite the above assertions, it is not advised to restrict calcium intake in stone formers because it may harm bone health and increase the likelihood of stones. Although a high-protein diet can increase urinary calcium, uric acid, and sulphate levels and decrease urine citrate levels, which may affect the likelihood of stones forming, it is not currently advised to limit protein intake to less than the current RDA for the treatment of stone disease (12).

A positive family history may influence the start and progression of urinary stone disease in addition to dietary and lifestyle factors. Positive family history may be a predictor of the course of the stone disease in such cases due to the early onset of urinary stone formation and the frequency of stone episodes. As a result, these patients should be closely monitored to avoid future recurrences (13)

On the other hand, as gaining weight is linked to a drop in urine pH, a higher body mass index and insulin resistance (also known as the metabolic syndrome) may be the etiological factors in uric acid nephrolithiasis (14).

Following treatment, recurrence of urinary stones is common. Age and blood hypertension operate as protective factors, lowering the likelihood of recurrence, while smoking, diabetes, and blood pressure are risk factors for recurrence (15).

1.1.4 Diagnosis of uroliths

Inadvertently finding stones when evaluating nonspecific symptoms or other issues is becoming more common. However, many times a patient comes with a "non-specific" abdominal pain.

A focused history is the first step in the diagnosis of urinary tract calculi. Systematically, blockage or stasis, infection, and metabolic abnormalities must be uncovered during first diagnostic tests (16).

In all patients with suspected calculi, a urine test should be done. The urine pH and the presence of crystals, which may assist to determine the stone composition, are significant findings in addition to the normal microhematuria. Patients with uric acid stones typically have an acidic urine, while those who develop stones because of infection typically have an alkaline urine (17).

Non-contrast computed tomography is considered the gold standard for imaging urinary lithiasis. For the first assessment of patients with suspected urinary stones, CT is the imaging modality of choice since it is extremely sensitive (up to 98%) and specific (96-100%) in identifying urolithiasis. This statement is due to its accessibility, speed, simplicity in image acquisition, lack of need for oral or intravenous contrast media administration, and capacity to identify pathologies other than urological ones like diverticulitis or appendicitis as well as gynaecological ones like haemorrhagic cysts or ovarian torsion that may mimic renal colic (18).

When evaluating children with suspected nephrolithiasis, ultrasonography should be performed as the primary imaging investigation. Non-contrast computed tomography should only be employed in cases when ultrasound is nondiagnostic and the likelihood of nephrolithiasis is still high (19).

1.1.5 Treatment

The majority of patients with acute renal colic can be treated conservatively by controlling their pain, staying hydrated, and anticipating stone passage. According to the kind of stone and the findings of the metabolic examination, dietary and pharmaceutical treatments have been proven to reduce recurring clinical occurrences by up to 60% (20).

The most frequently recommended first-line treatment for acute pain management is non-steroidal anti-inflammatory medications (NSAIDs) or paracetamol, with opiates coming in second (21).

The large percentage of guidelines also recommend using a-blockers to speed up the ejection of distal ureteral stones (5–10 mm) following shockwave or laser lithotripsy or to relieve stent-related discomfort (22).

For calcium oxalate stone producers, thiazides and alkaline citrates are typically recommended with varying degrees of grading, whereas urinary alkalization with allopurinol or febuxostat as a second line treatment is a typical treatment algorithm for urate stones, though with varying degrees of target urine pH (23).

Even though asymptomatic urolithiasis during pregnancy is prevalent, no further treatment is necessary. Regarding cause, upper urinary tract dilatation is a notable pregnancy alteration that affects 90% of expectant mothers during the seventh week of the pregnancy and can last up to six weeks after childbirth. In addition to being a significant risk factor for urinary infections and nephrolithiasis, hydronephrosis also causes an increase in urine stasis (24).

In the beginning, the patient should get proper pain management, and dehydration should be avoided at all costs. A prescription of fluids (oral hydration recommended unless there is accompanying vomiting), analgesics, anti-emetics (if necessary), and antibiotics (if infection is present) should be begun in patients with a proven ureteric colic during pregnancy (25).

Despite receiving medical care, urinary stones typically require surgery due to impaction, a related infection, unrelenting discomfort, or the financial burden the stone's presence causes. Below are several techniques for the management of urocystolites.

1.2 Management of uroliths:

1.2.1 Endourological treatment

Endourological treatment involves utilizing a rigid or flexible device to endoscopically treat the ureter from the ureteral meatus into the bladder in order to see, remove, or fracture the stone (26).

Numerous studies have examined retrograde and anterograde URS for upper ureteral impacted stones. Anterograde URS, which has a greater success rate and similar complication rates, should be the main course of therapy for an impacted upper ureteral stone, according to the authors' analysis of all the prospective randomized studies that were carried out in the prone position (27).

The use of URS in children is becoming increasingly prevalent thanks to the development of smaller, more robust endoscopes and the development of laser technology for the fragmentation of urinary stones. Staghorn stones, structural abnormalities, and previously failed endoscopic operations are relative contraindications for URS in children (28).

The endourological treatments used to treat lithiasis might conceivably impair renal function in several ways, including direct mechanical kidney damage or indirect methods (high IRPs, inflammation, or vasoconstriction of nearby renal arteries that encourage renal parenchymal damage) (29).

1.2.2 Percutaneous nephrolithotomy

Percutaneous lithotripsy, also referred to as percutaneous nephrocytotomy or NLP, is an endoscopic procedure that enables the removal of kidney stones by inserting tools like the nephroscope, lithotripsy probes (such as laser, ultrasound, etc.), and tweezers through a passage between the renal parenchyma and the skin (30).

Access problems might result in damage to the pleura and other visceral organs. Bleeding, infection, and insufficient stone removal round out the additional problems (31) Early diagnosis of problems requires the use of a well-standardized procedure and postoperative monitoring.

The PCNL treatment has undergone several revisions and advancements in the procedures and the devices since 1976 to obtain the greatest stone removal with the fewest problems. The access sheath is being reduced in size as one of them. Mini-PCNL/miniperc is performed with a sheath size of 14 to 20 F as opposed to standard PCNL, which has a sheath size of 24 to 30 F (32).

Mini PCNL appears to have fewer bleeding issues and shorter hospital stays than regular PCNL, but also longer operating room (OR) times and higher intrarenal pressure (33).

Moreover, a practical, adaptable, and minimally invasive technique for treating kidney stones is known as retrograde intrarenal surgery (RIRS), which involves the use of flexible ureteroscopes and efficient lithotripters for intrarenal pelvic disorders (34).

As retrograde endoscopic technology advanced, RIRS became more common, including for stones bigger than 2 cm. On the other hand, the recent development of aspirating sheaths together with the shrinking of percutaneous scopes and access sheaths have made PCNL less invasive, more effective, and appealing for tiny stones (35).

1.2.3 Extracorporeal shock wave lithotripsy

The management of upper urinary tract stones was modernized in 1980 with the introduction of shock wave lithotripsy (SWL). Proximal ureteral and renal calculi needed extensive surgeries with protracted recovery times before the SWL era. Over the past decades, SWL has been the most widely used therapy for kidney stones because it is a non-invasive surgical procedure with a low complication rate that permits same-day discharges. Shockwaves are used to break up kidney stones so they may be eliminated through the urinary tract (36).

Prior to ESWL, patient evaluation is extremely crucial. The gold standard for the diagnosis of upper urinary tract calculi in recent years has been computed tomography (CT). It has been claimed that several CT image-based variables, such as skin-to-stone distance, mean stone density, stone heterogeneity index, and variation coefficient of stone density, can help predict the result of SWL (37).

The ability of the fragments to be removed from the renal collecting system is a crucial prerequisite for the effectiveness of SWL. Patients with ureteral strictures, UPJ blockage, or any other anatomical condition that would restrict fragment transit must be disqualified. Patients undergoing combination SWL and PNL or combined SWL and percutaneous chemolysis are the only exceptions to this norm (38).

It is still difficult to come to a firm judgment on whether patient posture is the best choice for SWL therapy. The supine position for SWL may be the best choice since it has a higher distal ureteral stone-free rate than the prone position (39).

Children with significant stone burdens or prior urologic surgery have low success rates, although ESWL in the pediatric age range is cost-effective, safe, and has an acceptable re-treatment rate (40). Clinical and experimental research have shown that a shockwave frequency of 60/min is appropriate for youngsters (1 Hz). Avoiding overly many shockwaves and high-risk energy levels is necessary for performing lithotripsy in a safe and harmonic manner. The majority of ESWL in children are conducted under general anesthesia (or sedoanalgesia in older children) to prevent fear, discomfort, and movement as well as to maintain the stone under the shockwave target. Children's recurrent ESWL have a heavier weight, which must be taken into account (41).

Furthermore, patients who have radiopaque obstructive MPD stones greater than 5 mm in size that are situated in the pancreas head or body benefit from ESWL because it increases ductal clearance, which reduces discomfort and enhances quality of life (42). Children with chronic pancreatitis can also benefit from ESWL since it is both safe and effective (43).

Intravascular shock wave lithotripsy (IVL) was created as a development of this well-established treatment for renal and ureteral calculi. It employs a percutaneous device to generate acoustic pressure waves that give energy to dislodge both superficial and deep calcium deposits and help with the implantation of a vascular stent later on (44).

Stones are broken by shock waves through two primary processes: cavitation and direct stress. When a liquid experiences pressure changes, cavitation results. The ultrasonic probe transmits supersonic waves that alter the pressure of fluids. Consequently, bubbles develop. Cavitation bubbles group together and burst, eroding the stone's surface (45).

There are three types of ultrasonic wave generating technologies: electro-hydraulic, piezoelectric, and electromagnetic systems.

Shock waves are generated by electrohydraulic generating systems using an electric arc situated on the initial focus of an ellipsoidal reflector. The gadget is positioned so that the stone is on the ellipsoidal reflector's second geometric focus. Thus, the shock wave front travels from the first focus to the second geometrical focus of the ellipsoidal reflector, where the calculus is placed, via a water bath that acts as an acoustic coupling with the patient's body.

Piezoelectric systems work on the vibrating of piezoelectric materials in the presence of an electric field, which is typically created by a brief high-voltage pulse between two electrodes. The expansion and compression of piezoelectric actuators generate an ultrasonic wave, which propagates to a focal point in the circuit, where the stones are situated. When piezoelectric devices are made up of multiple parts, they form arrangements (also designated as arrangements or "arrays") of phase, that allow electronic focusing via the time lag of electrical pulses, providing dynamic positioning of the focal point.

Electromagnetic lithotripter produce a magnetic field. It employs an electrodynamic transducer, which consists of a coil in contact with a thin metal membrane in touch with water. To create a pulsed current through the coil, a high-voltage pulse is discharged through a capacitor. The succeeding current pulse across the coil creates a repulsive force in the metal membrane, forcefully compressing the water and producing a shock wave. A reflector or acoustic lens is employed to concentrate it on the stone. A reflector or acoustic lens is employed to concentrate it on the stone. Electrohydraulic technique necessitates electrode replacement every few thousand shockwaves, but electromagnetic generators may survive for millions of shockwaves. (46).

In terms of both effectiveness and complication rates, intermediate-frequency (80–90 shocks/min) and low-frequency SWL (60–70 shocks/min) exhibit superior treatment results than high-frequency SWL (120 shocks/min) (47).

Most guidelines divide stones into 3 size categories (10 mm, 10-20 mm, and >20 mm), with ESWL mostly advised for the first 2 groups. Is recommend using ESWL as the first line of therapy for stones less than 2.0 cm. For the management of caliceal stones larger than 2.0 cm, treatment should be customized (48).

The likelihood of cavitation will rise as a result of diuretics increasing urine flow. By creating a fluid film contact between the stone and the ureteric wall, fragmentation is made easier. The interface formed by the seepage of fluid behind the fissures may accelerate further disintegration of the core after the initial shockwaves shatter the cells' outer shell. Consequently, the cavitation bubble's impact is amplified as it collapses (49). That is, for people having SWL, diuretics greatly improve stone fragmentation. The gain in stone clearing, however, seems to be little (50).

Simple analgesics, NSAIDs, and opioids can all lessen shock wave lithotripsy-related discomfort to a level that is bearable for the treatment. While there are no glaring differences between NSAIDs and simple analgesics in terms of safety or effectiveness, analgesia is characterized as satisfactory more frequently for opioids than NSAIDs (51).

The position of the stones is a crucial indicator of SWL success rates. Although stones in lower calyces (LC) can be fractured by SWL just as well as those in other places, the clearing of stone pieces after SWL is less due to the lower pole's dependence. In the same location, percutaneous nephrolithotripsy (PCNL) had better stone-free rates than SWL for lower pole stones larger than 10 mm (52).

The connection between complications and ESWL application has been made. These usually involve infections, leftover stone pieces, and effects on tissues such the urinary, digestive, cardiovascular, genitourinary, and reproductive systems.

Following extracorporeal shock wave lithotripsy therapy, the creation of a stone street is a common consequence brought on by lithiasis fragments entering the ureter. It happens more frequently in individuals with complicated upper urinary tract lithiasis, with a frequency ranging from 1.1% to 24.2% of patients receiving ESWL. Stone street can occasionally act asymptomatically but can become aggravated by the presence of ureteral blockage, colic discomfort, or infection (52).

In terms of Steinstrasse, stenting prior to extracorporeal shock wave lithotripsy has several advantages over in situ extracorporeal shock wave lithotripsy. However, extracorporeal shock wave lithotripsy followed by stenting did not improve the percentage of patients without stones, and it also increased symptoms of the lower urinary tract (53). In the paediatric population, SWL without prior ureteral stenting is a successful and secure operation. Patients shouldn't have preoperative JJ stenting, especially if their stones are lower in size (54).

One of the forces used to break the stone during extracorporeal lithotripsy originates from the bursting of a cavitation bubble. However, this force may harm the tiny renal arteries, leading to a microhaemorrhage, the release of phlogosis-related cell mediators, and the invasion of inflammatory response cells.

Because of these microscopic lesions, germs that may be in the urine or even inside the stones themselves might enter the bloodstream and cause other connected issues (55).

Even though Emphysematous Pyelitis is extremely unlikely, it should be considered. Patients who experience fever and flank pain following ESWL should have an NCCT scan done to check for the presence of gas. In the emergency room, quick identification, evaluation, and treatment of these individuals are crucial. Medical intervention and percutaneous nephrostomy catheters are effective ways to obtain positive outcomes (56).

There are complications of ESWL that are a causes of kidney stone displacement and fragmentation and of the direct effects of shock waves on the tissues. The most visible sign of kidney injury is haematuria, which usually goes away within a few days. Less than 1% of patients experience collections of symptomatic fluids or perirenal, subcapsular, or intrarenal hemorrhages; however, if patients have routinely undergone a CT scan or MRI, the likelihood of finding a hemorrhage increases (57).

Renal subcapsular hematomas are one of the most dangerous and dreaded SWL side effects. With this complication, there is significant blood loss and negative consequences on renal function. Large arteries in the renal capsule can rupture, leading to subcapsular hematoma. The risk of this consequence is higher in people with high blood pressure.

It is plausible to anticipate other organs outside the kidney will experience stressors high enough to result in damage during ESWL. Extra-renal soft tissue injury can result with the use of ESWL for the treatment of kidney stones. Injury to the intestine, liver, spleen, or any other organ does not always indicate that the lithotripter was directed in the wrong place. Although the temporal and positional distribution of acoustic energy inside a lithotripter's focus zone normally serves to define the device, this region does not set boundaries for the high acoustic pressures produced by SWs. The focus zone is the region with the maximum acoustic pressure and energy density, although outside of this volume, SW pressures of the compressive and tensile phases of the pulse can be rather high (58).

There is enough clinical and experimental data to prove that there is no association between SWL and fertility and to rule out any long-term impacts on testicular or ovarian function. However, due to any potential harm that shock waves might bring to the foetus, pregnancy is an absolute contraindication to the technique itself, as proved repeatedly in the findings of several experimental research (59).

For the development of new treatment protocols to preserve kidneys throughout the therapy, a better knowledge of the process of ESWL-induced renal damage and the circumstances in which ESWL may produce such consequences is essential. Shock waves' main impact on renal tissue is vascular damage, which results in blood vessel rupture and blood pooling in the parenchyma. The renal papilla and medulla are particularly vulnerable to damage. Additionally, renal vasoconstriction causes hypoxia in certain regions of the renal tissue, which makes them susceptible to the formation of free radicals when reperfusion takes place. Following ESWL, those phenomena are seen concurrently in the kidney injury (60).

Shockwaves physically smash stones that are embedded in soft tissues while having a negative impact on the tissues around them. As a result, an inflammatory reaction to ESWL manifests, with potential kidney injury developing soon after the treatment and persistent fibrosis being induced, leading to long-term renal insufficiency.

Most of contemporary lithotripters use a dry treatment head that is connected to the patient via a high-acoustic-transmission medium, such gel or oil. The invention of the dry head was a significant step forward in the evolution of the lithotripter, allowing for the portability of lithotripters and greatly enhancing access to SWL. Unfortunately, using a dry-head device makes it challenging to obtain effective coupling. High diversity in coupling quality raises the possibility that clinical outcomes may also vary depending on coupling quality. Inadequate coupling might contribute to negative outcomes. More SWs are needed to shatter the stone when coupling is subpar. Even if the pulses' pressure amplitude is decreased, they still produce negative pressure that is considerably beyond the cavitation threshold, which means they still have the potential to damage blood vessels. It takes more SWs to shatter the stone because weak coupling is less effective, and the delivery of more SWs has a higher risk of harm. It matters how the gel is administered (61).

Urological care of urinary tract stone disease depends on a variety of variables, including stone size, location, quantity, anatomical structure, and chemical makeup (62).

Urinary stone composition must be precisely determined before to therapy since it has a significant influence on the right course of action. For example, uric acid stones can be treated medically using oral drugs that promote stone breakdown. While calcium oxalate monohydrate and cysteine stones are both somewhat resistant to being treated by SWL, struvite stones are responsive to it. The avoidance of recurring illness can also be aided by understanding the makeup of the stone (18).

A hereditary condition known as cystinuria causes a deficiency in the reabsorption of the amino acids cystine and dibasic, which can cause urinary tract calculi to form as early as childhood (63).

Patients with cystine nephrolithiasis tend to produce bigger stones than calcium stone formers, require more urological treatments, produce stones more frequently, and begin the condition earlier in life. They are also more likely than calcium nephrolithiasis patients to eventually suffer from kidney damage and chronic renal failure. Cystine stones can be surgically removed in a manner similar to other stones, however cystine is famously resistive to the extracorporeal shock wave lithotripsy (ESWL) except if the stones are less than 1 cm. Resistance to shock waves causes these patients to receive many sessions, with the side effects that this causes (64).

Cystine stones with uniform appearances on helical CT need more SWs for comminution than stones with poor X-ray attenuation areas did (65). Rough and smooth cystine stones cannot currently be consistently distinguished by HU in vivo, and as a result, HU cannot be used to determine whether stones are amenable to extracorporeal shockwave lithotripsy. This may be made possible by advancing CT scanner technology, which would reduce the need for several urinary tract procedures. However, a HU of 800 should trigger investigation of cystinuria when evaluating patients with unclear stone composition, and HU > 1000 are highly unlikely to be complete cysteine (66).

Unenhanced helical computed tomography (CT) is the imaging examination of choice for the initial evaluation of patients with suspected urolithiasis because it is extremely sensitive (>95%) and specific (>96%) in the confirmation of urolithiasis (18)(67). The application of CT in the management of urolithiasis has grown with the introduction of multi-detector CT (MDCT) and cutting-edge innovations like dual-energy CT (DECT) (67).

Along with having a high sensitivity for detecting urolithiasis, DECT also has improved capacity to analyse stone composition and distinguish between different stone types. Based on the idea that different compositions of stones have varied attenuation characteristics at various X-ray energy, DECT enables the measurement of stone composition. DECT distinguishes between uric acid and non-uric acid (calcium-dominant) stones because uric acid stones are formed of components with low atomic numbers (H, C, N, O) and their X-ray attenuation profile at multiple energies differs from that of non-uric acid stones, which are formed of elements with higher atomic numbers (P, Ca, S) (67).

Because of its capacity to identify stone composition and fragility, imaging study plays an essential role in treatment planning, follow-up, and treatment success evaluation.

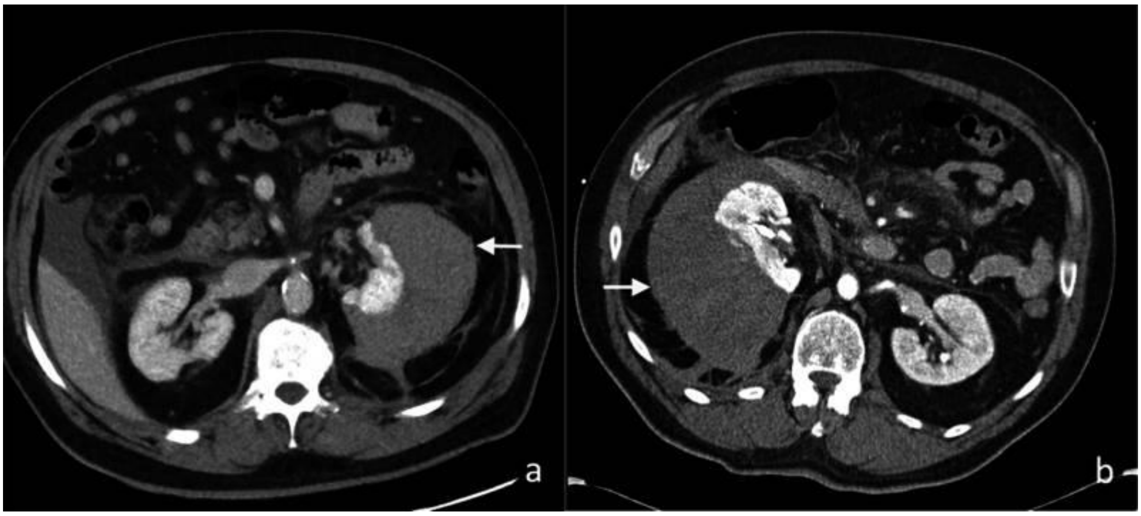
Even if the examination of these pictures allows for the total fragmentation of urolithiasis and hence the technical success of ESWL, problems owing to the traumatic impact of shock wave on bodily tissues, particularly the urinary tract, must be noted (68).

Shock waves' biological impacts on bodily organs and tissues may need a radiological examination. Such pathological symptoms consisting of micro-haemorrhage and inflammation, could become clinically important and identifiable by imaging methods.

The urinary and digestive tracts are the most involved organic problems during ESWL. In terms of the urinary system, the most common impact of ESWL is micro-hematuria, which is linked with no visible renal or ureteral alteration on imaging examination.

The possibility of ESWL consequences should be addressed in all patients, even when the procedure is regarded technically effective based on stone characteristics and there is no contraindication (68).

The incidence of a post-ESWL renal haematoma increases dramatically with patient age, the administration of a therapeutic dosage of low molecular weight heparin, and the existence of an unresolved urinary tract infection. The compression of the kidney because of the perinephric or subcapsular haematoma has been linked to systemic hypertension, commonly known as Page kidney. Repeated ESWL has been linked to ureteric perforation renal atrophy, and permanent renal function loss (69).



69: Axial contrast-enhanced CT scans of (a) perinephric haematoma (white arrow) and (b) subcapsular haematoma (white arrow) in two persons after ESWL.

A fixed ESWL intensity has an evident drawback known as the screening effect, in which the powder and tiny fragments formed by the cavitation bubbles and stress waves congregate around the leftover stones to attenuate and disperse the shock waves. The "ramping technique" of steadily increasing intensity was therefore devised. It was suggested that this strategy improves cavitation bubble generation and compensates for the screening effect.

The first lower shockwave energy constricts the renal arteries, making the kidney less vulnerable to harm during the subsequent application of a greater energy intensity (70).

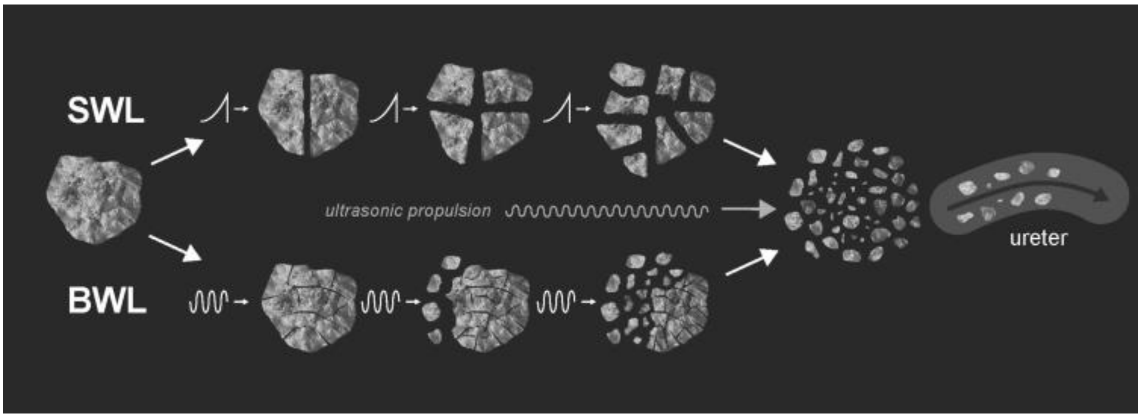
There is a threshold for tissue harm that is dependent on several variables, including the kind of lithotripter being employed, although nothing has been done to specify the boundaries of therapy. Since there is no reliable way to tell whether breaking is complete, patients frequently have more SWs than are necessary to remove their stones. Therefore, there is no doubt that SWL carries a risk of damage.

1.2.4 A new way: Burst wave lithotripsy and ultrasonic propulsion.

Around the world, ESWL is losing influence in the treatment of upper urinary tract calculi. The use of ultrasonic propulsion with burst-wave lithotripsy may offer fresh hope for the area of lithotripsy (71)

An experimental technique called burst wave lithotripsy uses targeted bursts of ultrasound to non-invasively shatter kidney stones (72).

Though lithotripter design has advanced, contemporary SWL machines continue to generate large peak pressures (30-100 MPa) in single-cycle pulses at a sluggish pace (2 Hz). In contrast, BWL is a cutting-edge technology modality that transcutaneously administers focussed, sinusoidal ultrasonic pulses at high rates (about 200 Hz) and low peak pressures (around 12 MPa) (73).



74: Harper JD, Metzler I, Hall MK, Chen TT, Maxwell AD, Cunitz BW, et al. First In-Human Burst Wave Lithotripsy for Kidney Stone Comminution: Initial Two Case Studies. J Endourol. 2021 Apr;35(4):506-11.

Through consecutive shock waves that produce localized tension and eventually a main fracture site within the stone, traditional ESWL non-invasively breaks stones (upper picture sequence). Usually, stones that have been subjected to SWL break into proportionately smaller fragments because of repeated shockwaves. In contrast, BWL stone comminution involves tiny fragments peeling from a single huge stone, which is more comparable to a "dusting" technique in laser lithotripsy (lower picture sequence) (74).

A clinical issue that makes it difficult to get patients totally stone-free is the existence of leftover stone particles in the urine collecting system. The fundamental issue with fragmented calculi in the urinary system is that these lingering fragments raise the possibility of new stone formation and symptom recurrence.

In order to relocate the stone transcutaneously into the kidney and the ureter, ultrasonic propulsion employs a brief burst of concentrated ultrasound pulses (75).

The user operates a handheld transducer that generates an ultrasound picture in real-time while sending ultrasound waves in the direction of a stone to carefully move it. The possible applications of ultrasonic propulsion include the movement of stones before to lithotripsy, enhancement of stone access during procedure, feedback on stone attachment, and fragment expulsion following procedure (76).

When BWL is used in conjunction with ultrasonic propulsion, there seems to be a synergistic impact on fragmentation efficacy. To achieve a complimentary impact, four concepts are addressed. The propulsion is physically ejecting particles that are just weakly linked to the stone, according to the first theory. The propulsion might also cause the stone to be reoriented, which would expose more than one side to the incident BWL pulses. The removal of dust and lingering cavitation bubbles from the stones or the area surrounding them during propulsion is a third option that might protect the object from BWL pulses. A fourth possibility is that UP pulses are aggravating existing stone fissures or that oscillating cavitation bubbles on the stone's surface are adding to the stone's total damage (77).

BWL can create cavitation in tissue, which can harm the kidneys, within specific ranges of ultrasound exposure parameters. Real-time ultrasound imaging is used to reveal a correlation between renal injury and the beginning of sustained cavitation in the renal parenchyma, suggesting that cavitation plays a similar role to SWL in injury (78).

During BWL treatment, real-time US monitoring enables the identification of injury-related cavitation. The user may then be able to change their course of treatment to lessen or stop kidney damage. MRI offers an additional, non-invasive approach to identify and measure damage (79).

Ultrasonic propulsion and extracorporeal shock wave lithotripsy are both transcutaneous procedures that employ concentrated acoustic energy that comes from an extracorporeal source. Ultrasonic propulsion, however, produces pulses with significantly lower pressures (12 versus 35-110 MPa) and lower total energy (25 versus 100-200 J) supplied to a kidney than SWL during an anticipated 20–40 minute therapy. Because ultrasonic propulsion delivers far less energy into the kidney than SWL does, ultrasonic propulsion damage should be less severe than that caused by SWL (80).

Burst wave lithotripsy (BWL) is an alternative to SWL. BWL has different physical characteristics than SWL in that it has a lower pressure and a higher frequency. The resultant cloud cavitation in BWL is anticipated to feature smaller bubbles and subsequently less violent bubble dynamics due to the wave's low peak amplitude. Large portions of incident waves can be scattered by the bubble clouds, which lowers wave energy downstream. Therefore, kidney stones nearby may experience energy shielding as a result of the bubble clouds in BWL.

Up to 90% of the entire energy of the burst wave that might normally be transferred into the stone is shielded by a thin layer of bubble cloud, indicating a significant potential loss of therapeutic efficacy for BWL owing to cloud cavitation (81).

Ultrasonic propulsion moves kidney stones by using concentrated bursts of ultrasound (US) energy. Commercial curvilinear C5-2 HDI probe with a 50-millisecond burst of 2 MHz pulses at a 73% duty cycle was the original probe utilized in the feasibility study.

The C5-2 probe had room for improvement in several areas. The probe's surface heating reduced the burst duration and the gap between bursts, which in turn limited the energy transferred to stone targets, the quantity and potency of each push, and the overall efficacy of successful stone repositioning. Furthermore, this probe's short focal length made it difficult to transfer energy effectively at greater depths. Finally, the smaller beam width could have made it more difficult to move several shards at once than to move groups of them.

A special probe was then created to improve energy delivery to stone targets in order to meet these restrictions. A water-cooled coupling interface, a wider focused beam width, a larger focal depth, and longer pulse durations are all features of the newly developed probe, known as the SC-X probe. When compared to the original C5-2 probe, the SC-X probe was found to eject clusters of stone pieces more successfully from a 30 mm phantom calix at both 4.5 and 9.5 cm depths (76).

1.2.5 Extracorporeal Lithotripsy by vortex acoustic beams

There is growing interest in employing arrays to produce increasingly complicated beam shapes and associated acoustic radiation force modes for contactless particle manipulation (82). As previously stated, ultrasonic propulsion was a new use for this phenomenon.

In human clinical studies, ultrasonic propulsion has been demonstrated to noninvasively relocate stones, and it is being used to evacuate tiny stones or remaining kidney pieces such that they pass spontaneously and maybe asymptomatically. The force can only be directed away from the transducer, which is a significant drawback of the existing technology. There are currently no known techniques for moving the stone along the complicated three-dimensional journey through the urinary system or transverse to the sonic beam. Transverse motion is needed to move tiny stones from the ureter into the bladder since the ureter is parallel to the skin's surface (83).

The exact contactless management of physical and biological elements at micrometric to nanometric scales holds enormous potential for advancement in domains as varied as microrobotics, tissue engineering, and micro/nanomedicine.

Acoustic trapping is a new technique that allows for non-invasive manipulation. It builds on the basic work of optical manipulation that earned the 2018 physics Nobel Prize (84).

Acoustic tweezers are a prominent technique in this area since they are non-invasive and biocompatible (85). Acoustic tweezers are a diverse collection of technologies that control bioparticles ranging in size from nanoparticle extracellular vesicles to millimeter-sized multicellular using sound waves. The phrase "acoustical tweezers" was initially used to represent the linear translation of trapped latex spheres and frog eggs in an acoustic environment (85) (86).

They discovered that a 270-um diameter latex particle or clusters of frog eggs may be trapped in a force potential well created by two collimated focused ultrasonic beams moving in opposing directions in water.

Acoustical tweezers are based on the premise that the radiation pressure of a concentrated ultrasonic beam can generate a stable force potential in the physical focal point. According to the physical parameters of the sphere, a tiny compressible sphere may be entrapped in the potential good and become stable in space (87).

Acoustic techniques offer specific benefits over other levitation methods, such as optical, magnetic, or electrostatic levitation, in that they can levitate a broader spectrum of materials in a variety of host fluids.

Because of the nature of light, optical tweezers have an absolute advantage in handling microscopic objects with great resolution; yet they are often confined to optical pure samples (88). Moreover, the highly concentrated laser beam-induced local heat would readily harm the targeted biological samples. Moreover, the power of optical tweezers is typically insufficient to handle relatively big particles or cells. Acoustic devices' easier setup would be less expensive than optical tweezers. The most significant advantage of employing acoustic devices is the fact that acoustic energy is less likely to harm biological samples. As a result, the acoustic technique is regarded as a non-invasive option for providing manipulation capacity for biological and biophysical applications (86).

Is preferred the term "acoustic tractor beam" over "acoustic tweezers" since it is more informative of the actual mechanics of this activity. In contrast to existing acoustic tweezers, this one uses a single source to capture and handle objects in 3D space by electrically guiding the acoustic beam. Subsequent research studies have investigated a 1.5 GHz 256-element focused ultrasonic array with homogeneous two-dimensional acoustic beam morphologies and high enough pressure restricted to a focal zone where big objects (such as kidney stones) may be captured and moved both along and transverse to the beam axis was produced (89).

The ESWL acoustic energy is focused in a relatively narrow area that surrounds the lithotripter's focal point and is the location of the kidney stone of interest. The size of the focus region and the maximum pressure that may be applied can both be adjusted. High targeting does not, however, guarantee that the treatment will be effective. Less shock wave energy is actually deposited into the calculus during more focused lithotripsies, leaving more shock wave energy to be deposited into the renal tissue.

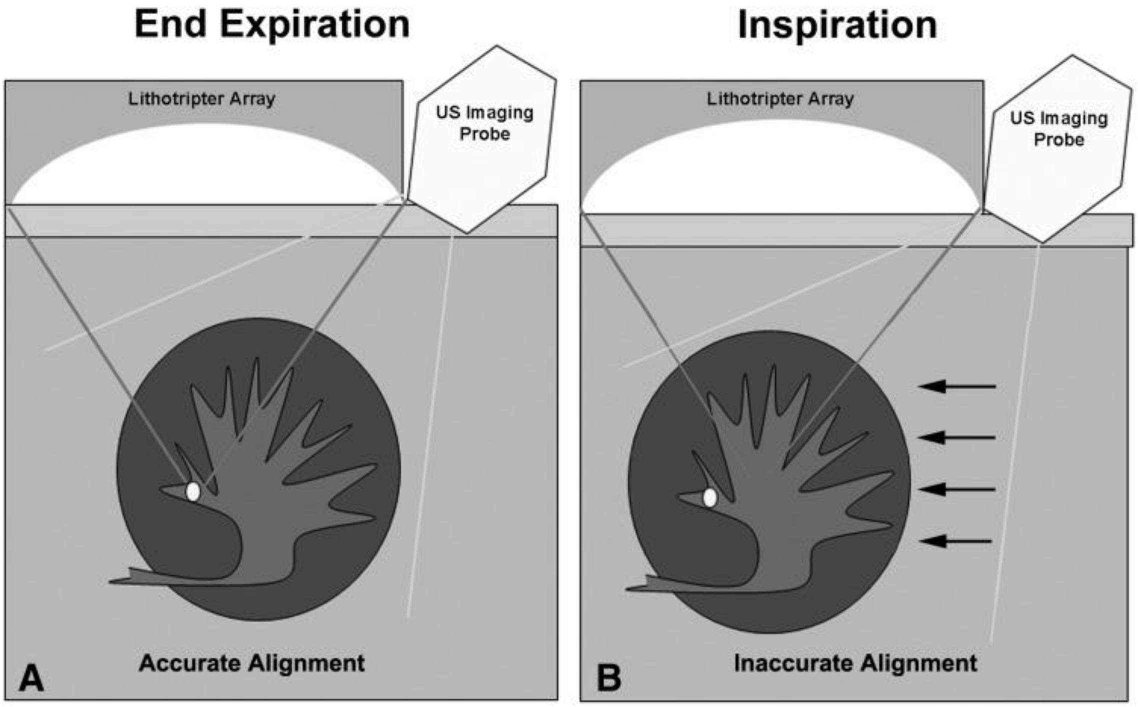
Most patients get the maximum number of shockwaves during their SWL, therefore efforts to guarantee precise targeting of the lithotripter focal zone are necessary, and the quantity of erroneous shockwaves administered should be limited.

The smaller tighter focal spot would at first glance, appear to be advantageous as it should allow for more accurate targeting and less damage to the tissue. However, in vitro experiments (where stones are stationary) indicate that the very high pressures, are no better at breaking stones and often have greater side-effects. The smaller focal spot lithotripters may not be as effective for two reasons. First, if the focal spot is smaller than the size of the stone then only a small volume of the stone will experience the full stress of the wave. This will affect the comminution efficiency of even a perfectly targeted stone. Second, stone motion due to respiration means that many shock waves will miss the stone (90).

Some writers suggest that expanding the focus region allows for fragmentation with reduced pressure peaks, lower energy density, and fewer negative effects.

The main concept behind a dual focus was to tailor the focusing region to the size and position of the computation. Big renal lithiasis must be treated with big foci to lower energy density, whereas ureteral stones can be treated with smaller foci. Another use for the dual focus might be to begin with modest foci and gradually increase to bigger focuses as the calculus decays, so reducing side effects (91).

Despite these advances in SWL technology, the percentage of beneficial shockwaves delivered throughout a therapy session remains unknown. Some of the shockwaves released are likely to miss the target stone totally and instead strike the surrounding tissue. These shockwaves solely cause kidney damage and have no effect on stone comminution. Regardless of stone size, respiratory excursion was sufficient to frequently shift the stone outside the lithotripter focus zone, at least for a brief period of time, throughout treatment of every stone (92).

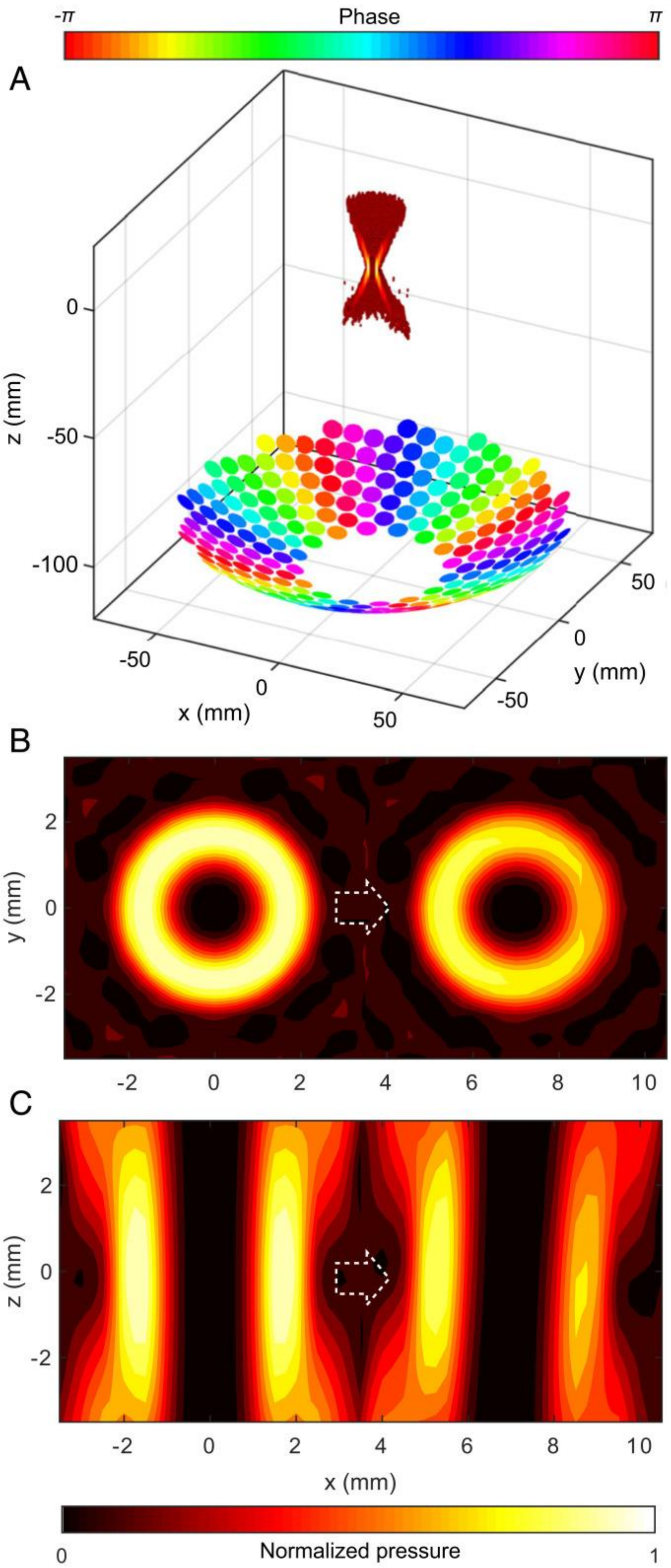


92: Diagram of configuration of shockwave lithotripsy machine and lithotripter array focused on the stone and the position of the associated ultrasound imager during (A) end expiration. With inspiration (B), the kidney descends with respiratory motion (arrows), moving the stone out of the lithotripter focus causing inaccurate alignment.

There are devices that operate with lower pressures and wider focusing regions, for example 20 MPa over a 20 mm focus, since the calculation may be more likely to remain inside the centralized location during treatment if the area is larger. Wide focal area lithotripsies are more favourable since they result in fewer kidney lesions (92).

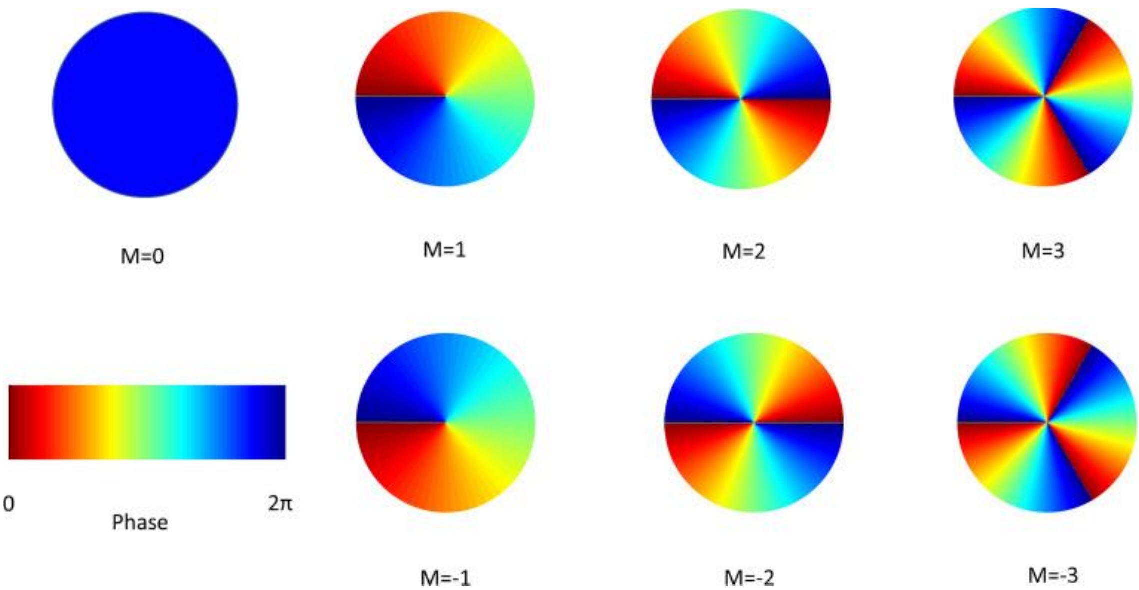
Acoustic tractor beam based on acoustic vortices have received a lot of interest because of their selective trapping capacity. Vortex beams enable the formation of negative acoustic radiation forces on particles, and as a result, this type of acoustic vortex has lately gained increased interest, owing to its direct practical uses in particle capture and handling systems.

Vortex beams (VBs) are structured beams with helical wavefronts carrying orbital angular momentum (OAM). The vortex is generated by altering the phase of the wave transmitted over a transducer surface, resulting in a helical wavefront. The phase must grow linearly with the circumferential angle in this situation, and the helicity must have a pitch that is continuous around the circumference. The consequence is destructive on-axis interference of the wave, but constructive off-axis interference, resulting in an intensity ring in the plane transverse to the beam axis. If the ring is wrapped around an item and transversely adjusted, force from the higher-intensity ring on one side of the object will "push" it back toward the center of the ring. An item may be controlled in two dimensions transverse to the beam axis using this technique. The image depicts the array and the empty hourglass structure of an acoustic trapping vortex beam (83).



83: A diagram of the element phasing and simulated focal-pressure field of a vortex beam with topological charge M = 4 (A), and transverse (B) and axial (C) slices of the simulated pressure field without focus steering and electronically steered 7 mm horizontally off the axis. The steering to the right is indicated by the white arrows. The pressure amplitude distribution is symmetric when the beam is focused on the array axis but is asymmetric when focused off the axis.

So that the helical wavefronts (vortices) are formed when nearby segments are pushed with sequential phase changes, resulting in a total phase shift of 2πM for the transducer's circumferential circuit (Fig. 1). M is the so-called topological charge for the emission and is an integer..., 2, 1, 0, 1, 2,... M = 0 denotes that all transducers are in phase, whereas negative and positive numbers denote clockwise and anticlockwise rotation of the helical wavefront generated. With M ≠ 0 there is a phase discontinuity along the axis of the transducer, hence the acoustic field along this line always has zero amplitude. As a result, ring-like traps with increasing diameters form as M grows. Using this technique, ring traps can generate an upward force to counteract the impact of gravity on a particle in a fluid. The ring also generates lateral inward pressures, causing the particle to get imprisoned in its core (93).



93: A representation of the topological charge for a segmented ultrasonic transducer. With M = 0 there is no phase difference in emission from the transducers. For integer M ≠ 0 there is a total phase change of 2πM when following a circumferential path around the transducer that gives rise to a helical wavefront. Positive and negative values of M give rise to clockwise or anticlockwise rotations of the helical wavefront. The phase discontinuity at the center of the array can be seen.

A practical issue with vortex beam capturing is the fact that helical wavefront has angular momentum, causing a particle in the trap to spin. This can cause instabilities and the particle to be ejected from the trap. To circumvent this issue, the sign of M can be abruptly altered so that the average angular momentum over time was zero. The location of the ring-like trap is electronically guided by further dynamical changes in the phasing of the transducers to create particle movement in the fluid (93).

Therefore, an item can then be relocated by moving the acoustic transducer manually, or by utilizing a transducer array and electrically directing the beam by varying the phase of the wave released by each element. An item may be controlled in two dimensions transverse to the beam axis using this technique (83).

The vortex beam method may also be used to control an item along its axis. The axial force of the beam is usually directed away from its source because backward scattering and vortex absorption by the object outweigh forward scattering, particularly if the object is big or dense.

Yet, when the force pushing the item away from the transducer is counterbalanced by gravity as the force drawing the object toward it, the object can be axially stabilized. After then, the beam may be electronically directed to move the item (94).

The shock waves employed in lithotripsy are large amplitude acoustic waves in contrast to vortex acoustic beams. They are impacted by the connection to the body and the existence of tissue through that they must traverse as they propagate through the body to the stone. After the shock wave hits the stone, a complicated transfer of energy occurs because the shock wave might be linked with compression and shear waves in the stone, causing cavitation in the surrounding fluid. The surrounding tissue is also vulnerable to significant physical stresses, which can cause harm (90).

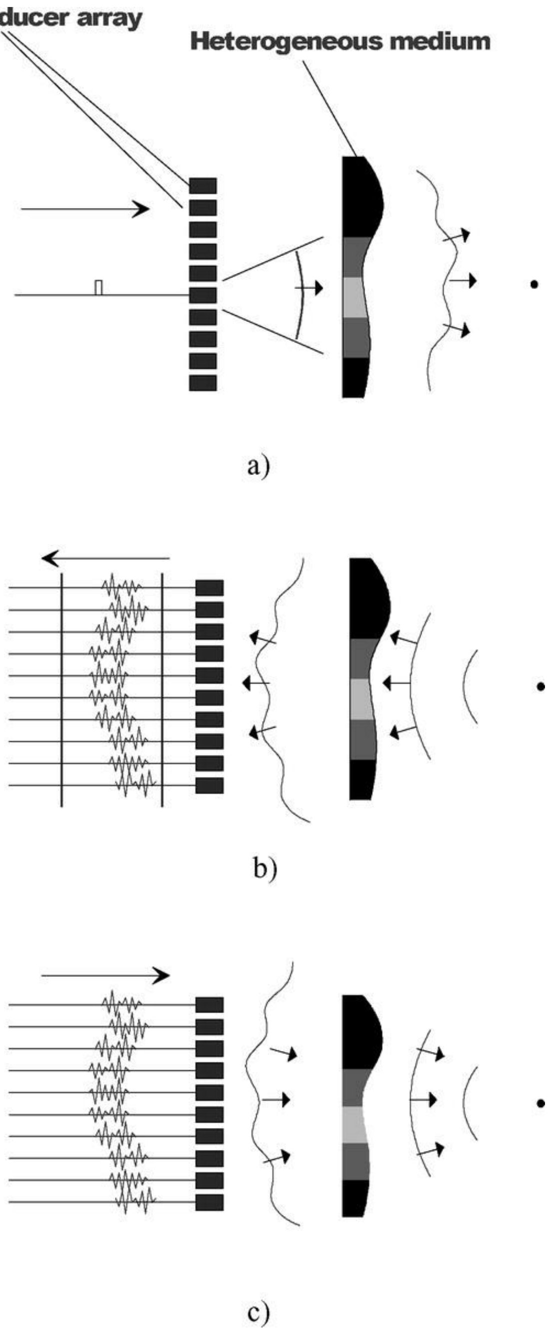
Vortex acoustic beams are ultrasonic and extremely powerful. These vortex beams concentrate on the computations, causing torques, shear forces, and strong internal tensions that efficiently fragment the calculations. The energy of ultrasonic stimulation (in the form of longitudinal waves) is extremely effectively transformed into mechanical energy by acoustic vortices (such as transverse waves). Because shear stress creation with such beams is more efficient, the ultrasonic field amplitudes necessary for fragment computations are substantially smaller than in extracorporeal shock wave lithotripsy approaches.

Thus far, most in vivo acoustic manipulation systems have demonstrated the capacity to manage only spherical objects. Nevertheless, actual items are rarely precisely spherical, culminating in spinning and sliding from the acoustic trap. A persistent trap is one where the forces on the particle are converging and the system is generally insensitive to tiny disturbances. Both the trapping force and the OAM in an acoustic vortex are proportional to the total power of the beam, implying that the rotational speed cannot be changed independently of the trapping force. This connection causes dynamic instability; for example, when large powers are required to build stiff trapping, the by-product is high OAM, culminating in instability and possibly particle ejection.

Although in vivo management of irregular shape objects is difficult, recent examples in the realm of sonic levitation may provide inspiration. Recently, an "acoustic lock" system based on twin acoustic traps was proven to confine non-spherical materials in the air (95).

Rapidly time-multiplexed acoustic vortices of opposing direction produce a time-averaged vortex, or virtual vortex, with independently configurable trapping forces and OAM. Acoustic virtual vortices are demonstrated to be capable of trapping and controlling the rotation speed of levitated samples. A virtual vortex with a big aperture (i.e., high helicity) is also proven to consistently capture particles with diameters greater than the wavelength (96) (97).

The diverse interior environments with irregular impedance distributions that are observed in humans present an extra difficulty for in vivo acoustic manipulation, resulting in wave dispersion and reduced acoustic trapping effectiveness. Employing time-reversal acoustics, which allows for more exact focussing of acoustic energy objects within the human body, is one technique to improve the effectiveness of acoustic trapping in complicated situations that have not yet been widely investigated. (98).



98: TRM focusing through inhomogeneous media requires three steps. The first step (a) consists in transmitting a wave front through the inhomogeneous medium from the array to the target. The target generates a backscattered pressure field that propagates through the inhomogeneous medium and is distorted. The second step is the recording step (b); the backscattered pressure field is recorded by the transducer array. In the last step (c), the transducer array generates on its surface the time-reversed field. This pressure field propagates through the aberrating medium and focuses on the target.

Acoustic trapping offers a lot of possibilities for urolithiasis disease and other uses. Acoustic tractor beams, when combined with BWL, can provide the missing element in the entire non-invasive therapy for kidney stones, with the extra benefit of employing no ionizing radiation. Additionally, it has the potential to be employed for various non-invasive medical applications (e.g., foreign object removal, blood clot therapy, or targeted medication administration), although the system is not yet prepared for commercialization or clinical usage (73).

2. JUSTIFICATION

In the non-invasive medical treatment called extracorporeal shock wave lithotripsy (ESWL), kidney stones are broken up into tiny fragments that can move more readily via the urine tract. Although though ESWL has been used for many years with great success, there is always potential for development and improvement in any medical procedure.

The efficacy of ESWL for specific kinds of kidney stones is one area that might use improvement. Small to variable stones respond well to ESWL, while bigger stones or those that are situated in certain regions of the kidney may necessitate more invasive procedures.

The minimization of potential adverse effects is another area in which ESWL might be improved. Although while ESWL is typically safe, treatment can have adverse effects such discomfort, bleeding, and tissue damage.

It is crucial to remember that several variables, including the size, composition, and placement of the stone, along with the patient's preferences and medical background, influences the choice of therapy.

Endourological laser therapy might sometimes be preferable to extracorporeal shock wave lithotripsy (ESWL).

Endourological laser therapy enables for more accurate stone targeting, lowering the chance of tissue injury to the surrounding area. This is crucial for stones that are close to critical structures like the kidney or the ureteral wall. Furthermore, although ESWL normally necessitates general anaesthesia, endourological laser therapy can frequently be carried out and under local anaesthesia or moderate sedation.

While ESWL is generally considered safe and effective, new methods are being created because of continuous lithotripsy research to enhance the procedure's results. Higher success rates and improved stone fragmentation may result from new lithotripter designs and advancements in shock wave production and delivery.

In summary, the development of new extracorporeal lithotripsy systems is important because it can improve patient outcomes, reduce costs, and make the procedure more accessible and comfortable for patients.

3. HYPOTHESIS AND PROPOSAL

Extracorporeal shock wave lithotripsy (ESWL) is one of the most effective treatments for treating urolithiasis, and it is often the initial treatment option for many patients. Despite its numerous advantages, undesirable consequences such as decreased renal function, perirenal hematomas, hypertension, urinary blockage, or infection might occur.

The mobility of the calculus relative to the focus point of the lithotripter during therapy is a significant disadvantage. This is related mostly to the patient's breathing movement. If no precautions are taken, some shock waves given will not reach the calculus and will impact the renal tissue, warming and perhaps damaging it. Furthermore, patient variables such as greater BMI were additionally reported as predictors of therapy failure. There are several technical obstacles connected with treating morbidly obese individuals, such as poor patient posture, attenuated shock waves, and challenging stone localization.

To prevent this, a system of numerous ring acoustic transducers is presented to accomplish focusing in a focal area while avoiding undesirable secondary targeting along the propagation path, the vortex beams.

The existence of remaining pieces is deemed a "failure" in other treatment methods (NLP, RIRS, URS, open surgery). In ESWL, lithiasis clearance results in a varied expulsion time. The existence of remaining fragments might have a role in late recurrence. Ultrasonic propulsion has the ability to provide a non-invasive and efficient method of moving the stones without the use of external propulsion devices.

Also, recent developments in optimizing ESWL outcomes concentrate on treatment factors such as initial characterisation of stone type, position, and size (or computations), optimization of acoustic coupling and recurring rate of waves, and optimization of shock wave sequence.

Burst Wave Lithotripsy employs high-energy shock waves to shatter the stones into tiny fragments that may be transported through the urinary system more readily. On the other hand, since vortex beams generate shear stress very efficiently, the ultrasonic field amplitudes required for fragment computations are substantially smaller than in existing extracorporeal shock wave lithotripsy approaches.

Bubble cavitation and shear stress have been demonstrated to play an essential role in the mechanical trauma induced by the shock wave. This technique also reduces the negative effects on the soft tissues that surround the solid.

Stone-related variables have a significant impact on ESWL success. When considering ESWL appropriateness, stone size is an important factor to consider.

Urinary stones can be diverse and heterogeneous in composition, with fluid-filled gaps that influence acoustic dispersion. Vortex beams can be modulated in intensity, phase, repetition rate, topological load, etc., according to the size, location, and composition of the mass to be destroyed, as well as to the energy that said beam transfers to the mass.

When a vortex beam is utilized to move an item that is irregularly shaped or heterogeneous, the item is more likely to spin and slide out of the trap.

To find real-world therapeutic uses, in vivo approaches must be capable of consistently catching and transporting non-spherical, irregular shape particles. In the future, twin acoustic traps could be utilized to trap non-spherical objects within the human body. Virtual vortices will provide up new possibilities for particle centrifuges and particle manipulation with variable sizes.

Acoustic tractor beam is a developing technique that may allow for the manipulation and full entrapment of macroscopic items such as stones, perhaps acting as a future addition to traditional treatment procedures.

4. OBJECTIVES

4.1. Primary objective

Conduct a complete and structured analysis of the most current extracorporeal lithotripsy systems in the management of kidney stones through a systematic review.

4.2. Secondary objective

Collect and evaluate the complications associated with using conventional extracorporeal lithotripsy systems in the treatment of kidney stones.

5. SEARCH METHODOLOGY

5.1. Methodological approach

A cross-sectional descriptive assessment of the publications found through a bibliographic review.

All data utilized in this study were gathered by direct consultation and Internet access to the scientific literature published in the major bibliographic databases, using the search methodologies outlined below.

5.2. Search strategy

The information for this study was gathered using sensitive profile search tactics that combined regulated vocabulary (MESH thesaurus) with free text in the "title" and "abstract" sections.

Two searches were conducted, each attempting to accomplish an objective.

In the primary objective, the words were "acoustic," "hunting," " vortex," " lithotripsy", "ultrasonics," "urolithiasis" and "kidney stone." The keyword phrases were concatenated using Boolean operators (AND) and (OR).

In the secondary objective, in English, the words were “lithotripsy”, “complication”, "side effect", "adverse effect" and “aftermath.” The keyword phrases were concatenated using Boolean operators (AND) and (OR) too. PUBMED and PMC were utilized to conduct a systematic search for papers and other scientific publications in the field of health sciences.

Parallel to the inclusion of the studies based on the defined criteria, manual searches were conducted on the bibliographic references of the included records to identify relevant papers on the study topic that may have gone missed in the bibliographic search strategy.

Due to the topic's recent modifications, the search and selection of articles took place between September 2022 and April 2023.

The tables displays the number of results from the bibliographic searches. The total number of papers obtained in the various databases is 24 in the primary objective and 43 the secondary.

5.3. Inclusion and exclusion criteria

5.3.1. Inclusion criteria

- Review articles that have a maximum age of 5 years
- Review articles dealing with current extracorporeal lithotripsy systems and the complications of associated with using conventional extracorporeal lithotripsy systems in the treatment of kidney stones, following the main the secondary objective, respectively.

- Review articles written in English.
- Review articles with full text for free

5.3.2. Exclusion criteria

- Review articles that do not contribute Articles on reviews that do not add to the review's aims or do not appropriately complement them.
- Review articles containing out-of-date information about vortex waves.
- Review articles containing complications of extracorporeal shock wave lithotripsy in animals.

5.4. Selection of documents

Following the search, the primary investigator meticulously examined the titles, abstracts, and keywords of the obtained records to determine their relevance to the established inclusion criteria.

Following an initial inspection of the documents, those that appeared to be of relevance for this bibliographic study were retrieved. Following that, the records chosen for inclusion were read again, and the reasons for exclusion were documented.

5.5. Limitations of the study

Due to the search tactics used to conduct this review, it is possible that relevant papers corresponding with the study's purpose will be lost. To try to overcome this restriction, comparable terms and synonyms of the same notion were included in the search techniques to increase the sensitivity of this review.

Because just the lead researcher and one collaborator were engaged in the research selection process, it is possible that significant studies were overlooked. This might imply that studies of relevance to this subject have been ignored. To reduce the risk of this happening, each of the studies collected has been thoroughly researched.

6. RESULTS

6.1. Articles included

Current extracorporeal lithotripsy systems in the management of kidney stones

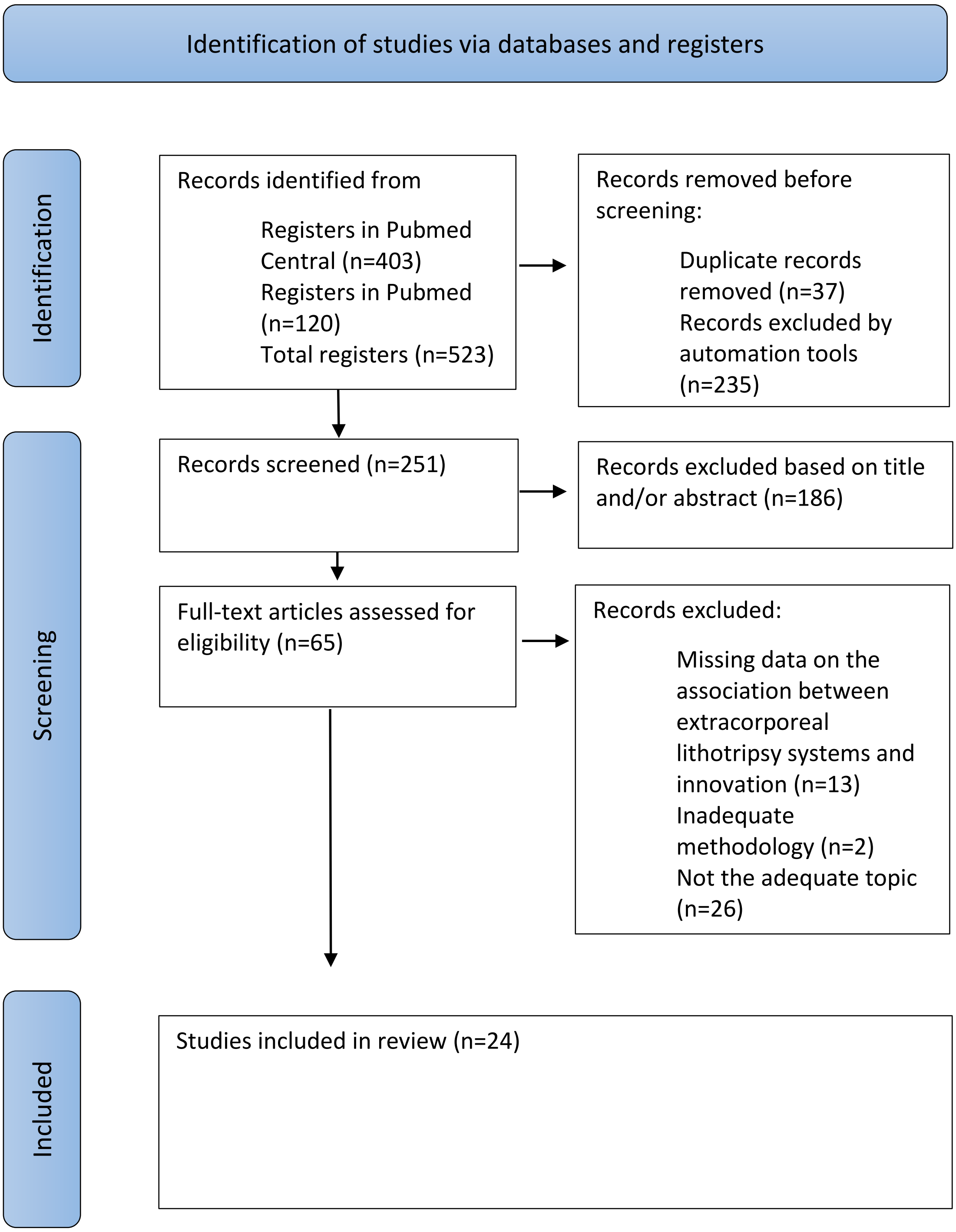


Figure 1. PRISMA 2020 flowchart of study selection process.

First, a total of 523 records (Pubmed Centra: 403; Pubmed: 120) were collected. A total of 65 articles were further evaluated carefully after duplication, automation tools and reviewing the title and abstracts. A total of 41 studies were further excluded, which lacked data on the association between extracorporeal lithotripsy systems and innovation, were not the adequate topic or not have adequate methodology.

Eventually, 24 articles were enrolled in this review.

Complications associated with using conventional extracorporeal lithotripsy systems in the treatment of kidney stones

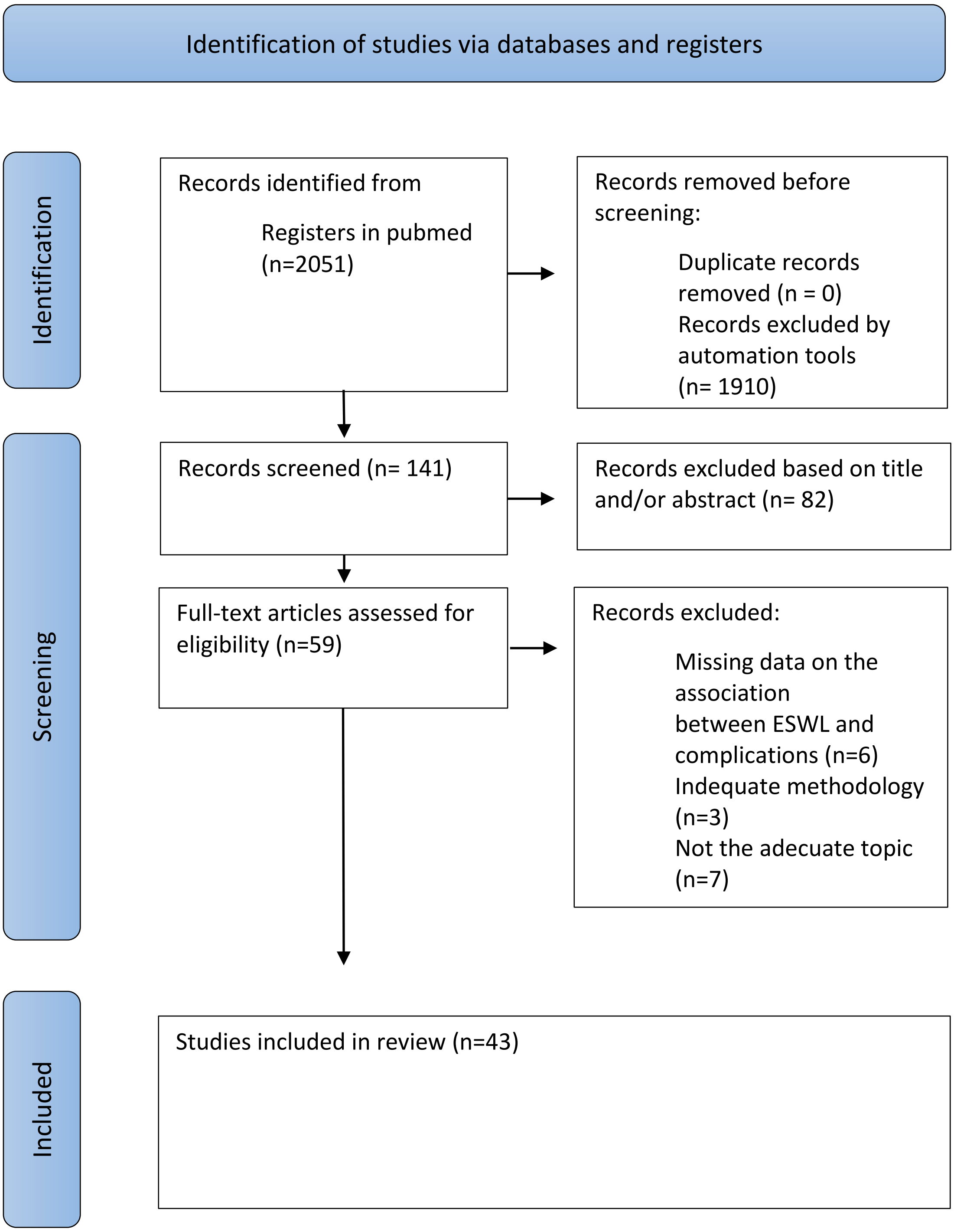


Figure 2. PRISMA 2020 flowchart of study selection process.

As shown in Figure 2, the literature search identified 2051 records. After removing duplicates and using automatic tools, remain 141 articles. After screening titles and abstracts, 59 articles were selected for full-text review, of which 43 studies met the inclusion criteria. The articles were divided into three tables for review and analysis. The first table included studies on complications of extracorporeal shockwave lithotripsy, the second included studies on complications of extracorporeal shockwave lithotripsy compared to other treatments and the third table, complications of extracorporeal shockwave lithotripsy combined to other systems.

The results and conclusions of each of the included articles have been included in a summarized way.

6.2. Tables of results

6.2.1. Current extracorporeal lithotripsy systems in the management of kidney stones

Table 1: Improvements in Extracorporeal Shock Wave Lithotripsy

Ref.	Year	Type of Study	Results	Conclusions
(141)	2022	Systematic review	With the improvement of modern (second and third generation) lithotripters, a growing number of children use ESWL to treat upper urinary stones.	Future technical improvements could not only further improve the efficiency of current procedures but also concomitantly reduced the complication rates.
(142)	2022	Retrospective incidence study	In-hospital SWL declined 74%. The percentage of SWL as an outpatient procedure increased between 2013 and 2018 from 36 to 46% of all performed SWL, while total SWL case numbers declined.	The fate of SWL in upper urinary tract stone management will depend on the implementation of recent technological developements and on finding a suitable framework for remuneration within the German health care system.
(144)	2019	Intervention study	In vitro, 71±2% of each artificial stone was fractured to < 2 mm in size. In vivo stone breakage averaged 63%. Only 1 out of 7 kidneys showed evidence of hemorrhagic injury in the treated area.	The sparker array consistently comminuted artificial stones demonstrating its ability to fracture stones like other lithotripters. Also, the sparker array caused little to no renal injury at the settings used in this study.
(147)	2023	Systematic review	The proposed technical modifications and adjunctives (using a camera during treatment, amplifying the focal zone, burst wave lithotripsy) are still to become the gold standard and recommended by the guidelines.	If we continue to see an evolution of newer models and this trend of artificial intelligence spiking, ESWL could become a strong competitor of ureterorenoscopy once again.
(148)	2022	Intervention study	In order to minimize the harm of FR caused by shock wave irradiation, the interval of the shock wave irradiation should be sufficiently larger than the FR persist time.	The recent trend to increase the output and shorten the shock wave irradiation interval to reduce the procedure time of ESWL is expected to have negative consequences for patient safety related to FR.

Table 2: New approachments

Ref.	Year	Type of Study	Results	Conclusions
(71)	2022	Systematic review	The BWL and ultrasound propulsion could be the new hope for ESWL to regain its position in the lithotripsy field.	A novel shock wave system of a combination of BWL and ultrasound propulsion technology seems to be a game-changer in treating urinary calculi.
(143)	2019	Systematic review	Recent in vitro studies have examined the combined efficacy of ultrasonic propulsion and BWL for stone fragmentation. Dispersion of comminuted stone fragments from the target with ultrasonic propulsion was hypothesized to increase BWL efficiency.	Ultrasonic propulsion has been shown to be safe and feasible in human subjects, and its clinical impact is beginning to be explored. BWL development is ongoing and progressing toward human trials.
(145)	2020	Experimental study	We showed that a BWL transducer with a broader focus can more effectively fragment large stones compared to a narrow-focus transducer with similar parameters and the same peak negative pressure.	We employed the IASA algorithm and rapid prototyping to design and fabricate a lens for a flat transducer to improve the effectiveness of stone comminution with BWL for larger stones.
(73)	2020	Systematic review	Burst wave lithotripsy and ultrasonic propulsion of kidney stones are novel, noninvasive technologies to fragment and reposition stones in an office setting.	Ultrasonic propulsion and BWL are safe, effective technologies that transcutaneously treat stones within the genitourinary system.
(146)	2018	Experimental study	The stones were fragmented with the new BWL transducer as well as with the existing conventionally focused BWL transducer which had a focus of 6 mm diameter in the focal plane.	Based on the observations of the rate of fragmentation, the new broadly focused transducer can fragment the stones 2.8 times faster than a conventionally focused transducer.

Table 2. Cont.

Ref.	Year	Type of Study	Results	Conclusions
(149)	2020	Systematic review	A clinical BWL system comminuted 70% of human stones completely within 10 minutes under conditions mimicking those in a human patient. The degree of comminution was determined by applying ultrasonic propulsion under real-time ultrasound guidance.	Current BWL parameters are robust and may be made more efficient and maintained safe by increasing output to a level just below where a cavitation cloud is detected.
(150)	2020	Experimental study	Guided wave mode generation, propagation, and reflection are important in the production of stresses causing fractures in stones during BWL.	Observations show the development of regular patterns corresponding with specific guided wave modes in models with rectangular and circular cross section, arising notably from shear waves generated by the burst.
(78)	2019	Experimental study	On average, 87% of the stone mass was reduced to fragments <2 mm. In three of five treatments, stones were completely comminuted to <2-mm fragments.	Burst wave lithotripsy can produce stone fragments small enough to spontaneously pass by transcutaneous administration of US pulses. The data suggest that such exposures produce minimal injury to the kidney and urinary tract.
(76)	2019	Non-controlled trial	Ultrasonic propulsion was successfully able to move at least one stone target a distance ≥ 3 mm in 95% of kidneys under ureteroscopic observation and 79% of kidneys with US observation.	Ultrasonic propulsion was shown to be safe, and it effectively repositioned stones in 95% of kidneys despite positioning and access restrictions caused by working in an operating room on anesthetized subjects.
(151)	2018	Experimental study	The result indicates that up to 90% of the energy of the incident burst wave can be absorbed/scattered by bubbles that would otherwise be transmitted into the stone.	This series identified the dynamics of cavitation bubble clouds in BWL and quantified the energy shielding of kidney stones by the bubbles, the latter of which may cause loss of efficacy of stone comminution.

Table 2. Cont.

Ref.	Year	Type of Study	Results	Conclusions
(152)	2018	Experimental study	Repositioning of stones in humansand breaking of stones in a porcine model have been demonstrated using the same 350-kHz probe. Experiments of burst wave lithotripsy (BWL) demonstrate that are safe and effective.	Breaking of stones with specific burst wave lithotripsy parameters is safe and effective in animal studies, and these data have been submitted in an application for an investigational device exemption for human trials.
(81)	2018	Experimental study	Results indicate that the magnitude of the shielding reaches up to 90% of the energy of the incident burst wave that otherwise transmits into the stone.	It is discovered a strong correlation between the magnitude of the shielding and the amplitude of the backscattered acoustics, independent of the initial condition of the cloud.
(153)	2022	Non-controlled trial	Stone displacement by the ultrasound bursts occurred in 66%. Distal ureteral stone clearance was observed in 86% of subjects in an average of 3.9 days. On average, pain scores significantly decreased during the investigative procedure, and anticipated events were mild and self-resolved.	This study supports the efficacy and safety of using ultrasonic propulsion and burst wave lithotripsy in awake subjects to reposition and break ureteral stones to relieve pain and facilitate passage.
(154)	2022	Non-controlled trial	In this first feasibility study of BWL in humans, 21 of 23 (91%) stones showed fragmentation and 9 of 23 stones (39%) were fragmented completely within 10 minutes.	The first study of BWL in human subjects resulted in a median of 90% comminution of the total stone volume into fragments ≤2 mm within 10 minutes of BWL exposure with only mild tissue injury.
(155)	2023	Systematic review	Kidney stone fragmentation and repositioning by BWL and ultrasonic propulsion have shown promising results in preclinical and clinical trials.	Ultrasonic propulsion and burst wave lithotripsy offer a powerful, handheld tool to target, break, dislodge, and expel stones and stone fragments from the urinary tract in an ambulatory setting.

Table 2. Cont.

Ref.	Year	Type of Study	Results	Conclusions
(156)	2022	Experimental study	Lowering the PRF of the exposure from 40 Hz to 10 Hz significantly increased the pressure amplitude needed to produce tissue cavitation.	Lowering pulse repetition frequency was found to significantly increase the pressure amplitude needed to produce sustained cavitation, and controlling this parameter may offer a mechanism to avoid sustained cavitation and renal injury during BWL procedures.
(75)	2021	Non-controlled trial	For Participant A, a ureteroscope inserted after 9 minutes of BWL observed fragmentation of the stone to <2 mm fragments. Participant B tolerated the procedure without pain from BWL, required no anesthesia, and passed the stone on day 15.	In these initial two participants, BWL appeared safe and effective in breaking the renal stone and was tolerated without pain in an awake participant who later passed the targeted UVJ stone.
(83)	2020	Experimental study	Specific beams were synthesized with a multielement ultrasound phased array and demonstrated to manipulate a 3-mm glass sphere inside a living body, without harmful effects to the intervening tissue.	Specific beams were produced with a focused ultrasound phased array to synthesize acoustic traps. Such traps were found to capture and move spherical objects w and in vivo. The spheres were both levitated and electronically steered along preprogrammed paths.
(89)	2018	Experimental study	The output was successfully equalized to produce uniform vortex beams in the focal plane.	A 256-element array system was characterized . Element outputs were equalized and the ability to generate uniform vortex beams that potentially could be used for the acoustic manipulation of kidney stones was demonstrated.

6.2.2. Complications associated with using conventional extracorporeal lithotripsy systems in the treatment of kidney stones

Table 3: Analysis of complications of extracorporeal shockwave lithotripsy

Ref.	Year	Type of Study	Sample (n)	Results		Conclusions
				n	%	
(40)	2021	Systematic review and meta-analysis	37	8	21,6%	ESWL is an effective minimally invasive technique, with low cost and morbidity, reproducible and safe for the treatment of stone disease in children. Even though lithiasis size seems to be a significant factor in ESWL success, in combination with other lithotripsy procedures it can reach very high rates of stone clearance.
(102)	2022	Systematic review and meta-analysis	115	12	10,4%	Extracorporeal shock wave lithotripsy continues to be a safe and effective option for managing simple calculi in distal ureters with a diameter of ≤10 mm. The stone size and BMI remain significant predictors of treatment outcome.
(106)	2021	Case report	1	1		Although ESWL is generally considered safe and effective treatment; however, major complications have been reported to occur in less than 1% of patients. One of the extremely rare complications is the development of pancreatitis and pancreatic pseudocyst.
(56)	2020	Case report	1	1		Patients presenting with fever and flank pain after ESWL should be evaluated for the appearance of gas with an NCCT scan; although rare, EP should be kept in mind. Quick diagnosis, examination, and treatment of these patients in the emergency department are important. Successful results can be achieved through medical treatment and percutaneous nephrostomy catheter.

Table 3. Cont.

Ref.	Year	Type of Study	Sample (n)	Results		Conclusions
				n	%	
(110)	2022	Case report	1	1		Large Perinephric hematoma following ESWL is a rare complication. Hemodynamically stable patients with no active extravagation or pseudoaneurysm/AV malformation, can be managed conservatively without loss of renal function.
(111)	2019	Retrospective incidence study	96	44	45,83%	ESWL was indicated and performed in a similar way as for younger populations, except for larger stones that needed additional sessions. The complication profile seemed similar to that in the general population. Octogenarians undergoing ESWL may have some survival benefit, justifying active treatment in this population.
(112)	2020	Case report	1	1		ESWL may cause an abdominal aortic rupture, especially for patients with a heavily calcified aortic wall. We suggest that all patients with atherosclerosis being considered for ESWL undergo imaging examinations both preoperatively and during follow-up.
(113)	2019	Case report	1	1		Close monitoring and follow up is indispensable, as any deviation from the normal course following ESWL should be thoroughly observed.
(114)	2020	Retrospective incidence study	1012	20	1,97%	ESWL is an effective and safe treatment modality in the paediatric age group that provides high SFRs. However, sufficient technical equipment and increased experience affect the outcomes positively, and age, BMI, and stone location, size, and composition are significant factors that predict the success of ESWL.
(115)	2023	Meta-analysis	488/488	70/77	14,34%/15,77%	eESWL can significantly improve SFR, shorten SFT, and reduce auxiliary procedures.

Table 3. Cont.

Ref.	Year	Type of Study	Sample (n)	Results		Conclusions
				n	%	
(118)	2023	Systematic review	16	16		Although bowel perforation is rare, and renal colic is the main complication after ESWL, patients with acute abdominal pain few hours after the procedure should undergo a proper physical exploration to search for peritoneal irritation.
(119)	2018	Non-randomized, controlled trial	173	18	10,40%	The best results in stones fragmentation and less analgesia requirement were demonstrated in the electromagnetic lithotripter group. No differences were demonstrated considering the need for emergency room after the treatment.
(120)	2018	Retrospective incidence study	80	11	13,75%	Short-interval SWL sessions are safe and effective in treating upper ureteral stones. These sessions do not increase complication rates, so they are advisable as an active therapy for ureteral stones, especially if fast results are prioritised.
(121)	2019	Retrospective incidence study	476	59	12,4%	High pain perception does not correlate with the effect of ESWL. Pain scores during ESWL sessions remain high. Therefore, additional analgesia is recommended to improve patient comfort. stone size and stone location are predictive factors on the outcome of ESWL.
(124)	2021	3 case report	3	3		Our study reminds physicians that patients developing acute renal insufficiency after ESWL should lead to the suspicion of anti-GBM disease and in-time diagnosis and treatment.
(125)	2019	Retrospective incidence study	215/120	7/4	3,25%/3,33%	E-ESWL is an effective and safe treatment method for colic caused by a ureteral stone. We recommend con-ducting ESWL within 24 hours of pain development. In addition, if the patient is 65 or younger, with a HU of 815 or less than, has a stone size 10 mm or smaller, and has a mid to distal stone location then e-ESWL is especially recommended as a more effective lithotripsy result is expected.

Table 3. Cont.

Ref.	Year	Type of Study	Sample (n)	Results		Conclusions
				n	%	
(126)	2020	Case report	1	1		Subcapsular renal hematoma should be suspected in patients with pain in the lower back or acute flank after ESWL, especially in patients who do not respond to analgesic treatments. Supportive care and observation are a treatment of choice.
(127)	2021	Case report	1	1		Patients who present with signs of persistent abdominal pain post-ESWL should be observed. If symptoms persist, increase in intensity or there is a general deterioration of the patients' hemodynamic status, prompt surgical intervention is crucial for definitive diagnosis and management.
(128)	2018	Case report	1	1		Clinicians should understand and be aware of the possibility for more serious complications after ESWL. Although the possibility of post ESWL psoas abscess is very low, a high degree of clinical suspicion and CT imaging are essential for timely diagnosis and appropriate management to be initiated at the right time.
(129)	2023	Prospective cohort	568	42	7,39%	SWL had equivalent efficacy with more safety and cost benefits than F-URS in treating patients with solitary non–lower pole kidney stones ≤ 20 mm.
(130)	2018	Case report	1	1		Bilateral simultaneous ESWL for bilateral renal stones does not affect the renal function in the long-term outcome but still carries the risk of bilateral steinstrasse, bilateral obstruction, and ARI.
(131)	2018	Case report	1	1		SWL, although minimally invasive, is not without complications. Proper patient selection with individual evaluation of preprocedural risk factors with respect to the presence of urinary tract infection and obstruction should be performed to avoid post-SWL devastating infective complications.

Table 3. Cont.

Ref.	Year	Type of Study	Sample (n)	Results		Conclusions
(132)	2020	Case report	1	1		Arterial pseudoaneurysm may occur after ESWL in patients with Behçet disease. ESWL should be performed under the supervision of a vascular surgeon and with perioperative observation and immediate post-ESWL Doppler ultrasound after each session.
(133)	2020	Case report	1	1		Splenic injury is a rare complication of ESWL and is life-threatening.
(137)	2020	Case report	1	1		The likelihood that an LVAD patient will require noncardiac surgery will increase. Peri-procedural anticoagulation management of these patients is complex and requires a delicate balance between avoiding bleeding complications and avoiding pump thrombosis.
(138)	2023	Case report	1	1		Spondylodiscitis after complicated ESWL is an extremely rare possibility. Early diagnosis/treatment may limit the risk of lumbar stenosis occurrence.
(139)	2019	Case report	1	1		Renal hematoma following ESWL for renal calculi is a rare but generally benign condition only requiring conservative management. Few serious complications occur requiring more invasive therapy. Active bleeding, though rare, should be considered despite hemodynamic stability, thereby warranting further investigation.
(140)	2019	Retrospective incidence study	197	12	6,09%	Although the stone size and to a negligible extent, the stone location and presence of stent may affect the stone clearance, nevertheless a significant improvement in success rate has been observed by use of new shockwave lithotripsy machines.

Table 4: Analysis of complications of extracorporeal shockwave lithotripsy compared to other treatments

Ref.	Year	Type of Study	Sample (n)	Results		Conclusions
				n	%	
(99)	2019	Systematic review and meta-analysis	2342	293	12,5 %	SWL ranked the lowest of the treatments because of its lowest success and stone-free rates compared to PCNL
(100)	2022	Systematic review and meta-analysis	1592	168	10,55%	For 1–2-cm urinary stones, f-URS can achieve a higher SFR than SWL while having a lower retreatment rate, number of sessions, and auxiliary procedure rate. For urinary stones <1 cm, there was no significant difference in SFR between SWL and f-URS groups. The SWL group has a shorter operative time and hospital stay than the f-URS group.
(103)	2022	Case-control study	90	10	11,12 %	ESWL is effective in treating patients with urinary calculi with a simple, safe, and quick operation and a low incidence of adverse events, as it effectively reduces the incidence of complications, accelerates the recovery of patients, and improves their quality of life.
(104)	2020	Randomized clinical trial	75	16	21,3%	Compared with SWL, URS had significantly higher stone-free rates in patients with proximal ureteral stones. Treatment costs and hospital stay were lower in the SWL group, whereas complication rates were comparable.
(105)	2018	Prospective cohort	999	37	3,7%	Treatment success was mainly dependent on stone size and treatment modality. URS might be the better treatment option for previously untreated kidney stones 5–20 mm, with similar morbidity but higher stone-free rates and fewer reinterventions than ESWL.
(107)	2018	Prospective cohort	200	49	24,5%	The stone-free rates after single procedure were significantly higher for the URS group while the complication rates were comparable in both groups. Treatment costs were significantly lower for the ESWL group.

Table 4. Cont.

Ref.	Year	Type of Study	Sample (n)	Results		Conclusions
(108)	2021	Systematic Review and Meta-Analysis	68	25	36,8%	FURS and SWL are effective and safe treatments for patients with HK with stones (<20 mm). Moreover, FURS has greater clearance rates and lower complication rates than SWL.
(109)	2021	Randomized Controlled Trial	21	2	9,52%	Owing to premature closure of this trial, the power was insufficient to formally compare URS and SWL
(116)	2021	Prospective randomized study of a cohort	90	16	17,8%	The results for URSL were superior with a lower re-treatment rate, rapid stone clearance in a very short time, and less radiation exposure.
(117)	2020	Retrospective cohort	73	19	26%	RIRS was superior in terms of total procedure and anesthesia duration, while SWL was superior in terms of numbers of anesthesia sessions and active procedure sessions. Both methods have similar success, complication, and auxiliary treatment rates for ≤2 cm upper urinary system stones.
(122)	2020	Systematic Review and Meta-Analysis	1904	203	10,66%	PCNL had the highest SFR and lower auxiliary procedure and retreatment rates than ESWL or RIRS. No significant difference was seen versus RIRS in complications regarding stones < 2 cm.
(123)	2019	Systematic Review and Meta-Analysis	691	70	10,13%	ESWL is confirmed to have the lowest SFR, the higher retreatment rate and auxiliary procedure rate, but a shorter operative time and the shortest hospital stay. The overall complication rates among the three therapies are comparable.
(134)	2019	Systematic Review of Comparative Studies	62	9	14,52%	For a stone <2 cm in HSK, both SWL and URS are safe treatment modalities. URS alone is a more feasible and sufficient option for stone in HSK <2 cm than SWL with possibilities of a second session.
(135)	2021	Retrospective cohort	1317	169	12,83 %	At 12-months follow-up, unplanned emergency visits and re-admission rates were significantly more after flexible URS.
(136)	2021	Retrospective study	48	9	18,75%	MPCNL should be used clinically for the treatment of urinary calculi in pregnant women.

Table 5: Analysis of complications of extracorporeal shockwave lithotripsy combined to other systems

Ref.	Year	Type of Study	Sample (n)	Results		Conclusions
				n	%	
(101)	2022	Retrospective cohort	87	8	9,3%	It was concluded that the application of shock wave lithotripsy before ureteroscopic lithotripsy in proximal ureter stones did not affect the success. Although the results are similar in terms of postoperative infection, shock wave lithotripsy application has been found to increase the risk of stone impaction into the mucosa and ureteral laceration.

7. DISCUSSION

Urolithiasis is one of the most prevalent urological conditions, with one out of every ten persons developing kidney stone sickness at some point in their lives (1). Urolithiasis can be problematic since these stones can cause significant pain, inflammation, infection, hematuria, kidney degeneration, and an impact on the healthcare system due to their high prevalence and recurrence (8).

Multiple therapies for urolithiasis have been recorded, including ESWL, percutaneous nephrolithotomy, retrograde intrarenal surgery, and traditional open surgery, among others.

ESWL has been a safe and successful non-invasive therapy option for nephrolithiasis since 1982. (36). The stone is broken by extracorporeal shock energy delivered by ESWL. Shock waves break stones by two basic processes: cavitation and direct stress.(45) However, some of the shock waves may cause harm to neighbouring tissues such as the kidney, liver, or pancreas. By ensuring that the shock waves are adequately focused on the stone and that the patient's anatomy is taken into consideration throughout the treatment, the danger of tissue injury can be reduced. (58, 60)

Current developments in optimizing ESWL outcomes concentrate on treatment factors such as initial characterisation of stone type, position, and size (or computations), optimization of acoustic coupling and repeating rate of waves, and optimization of shock wave sequence.

However, because the tissues around the stone are always fragmented by high-intensity ultrasound pulses, these tissues are vulnerable to mild or serious problems.

Pain, bruising, swelling, or bleeding in the treated region may be symptoms of tissue damage caused by ESWL. More significant problems, such as internal bleeding or organ damage, may occur in rare circumstances. In most situations, tissue damage by ESWL is minimal and transitory, and patients can recover totally with adequate therapy and follow-up care. (55)

In this paper we collect information on innovative techniques that aim to overcome some of the disadvantages of shock wave lithotripsy.

Improving the precision of the shock waves is one strategy to reduce negative effects. The surrounding tissue is less likely to be harmed if the shock waves are directly aimed at the stone.

To increase the focality, ultrasonic propulsion can be used. Ultrasonic Propulsion is a method used to transport kidney stones from the kidney or ureter to a more readily treated or for the expulsion. (75)

Ultrasonic Propulsion is frequently used in concert with other methods, such as BWL. BWL employs short, high-energy bursts of sound waves that hit directly at the stone, allowing for more precise stone targeting. In comparison to ESWL, this may result in fewer adverse effects. (81)

A very current focusing technology are acoustic beams. Acoustic beams are high-intensity focused ultrasound (HIFU) waves that are aimed towards the kidney stone in order to break it down into smaller fragments that can be passed through the urinary tract more readily. A transducer put on the skin and focused on the area of the kidney stone generates the waves. It is a system of multiple rings, which prevent unwanted secondary targeting along the direction of propagation (84).

On the other hand, vortex beams are a form of sound wave that produces a spinning pattern of sound waves. This generates an energy vortex that may be directed at the kidney stone to break it down. Vortex beams have the benefit of being more exact than acoustic beams and may be aimed towards particular portions of the kidney stone.

Unlike standard shock wave lithotripsy, which creates a shock wave that travels throughout the body, vortex beams are more confined and may be focused on the kidney stone more accurately. This means that the energy is focused on the stone rather than diffused throughout the body, potentially lowering the risk of tissue injury.

Furthermore, the vortex beam's circular motion may contribute to its capacity to inflict less tissue damage. Because the beam rotates, it is less likely to produce hot spots or areas of high energy density, which can cause tissue damage.

Vortex beams are an intriguing field of study for the treatment of kidney stones and other medical disorders due to their accuracy and targeted energy delivery.

In summary, because of its high success rate and low complication rate, ESWL is the most often used treatment for patients with renal or proximal ureteral lithiasis up to 2 cm in diameter. However, because problems might arise during any medical operation, it is necessary to develop new techniques that allow the efficient fragmentation of stones using mechanical waves with reduced amplitudes.

8. CONCLUSION

ESWL have been demonstrated to be effective in the treatment of urinary calculi, with success rates ranging between 80 and 90%. However, there are some discrepancies in the therapy safety and efficacy.

In terms of safety, ESWL is widely regarded as a risk-free technique with minimal significant consequences. It may, however, cause considerable discomfort during the surgery and may necessitate the use of anaesthetic. Damage to neighbouring tissues, such as the kidney or bladder, is also possible.

Overall, the decision between ESWL and URS will be influenced by a number of criteria, including the size and placement of the stones, the patient's general condition, and the treating physician's preferences. URS can achieve a greater SFR than SWL for 1-2 cm urinary stones while having a lower retreatment rate, total number of sessions, and auxiliary procedure rate.

Lithiasis size also seems to be a significant factor in ESWL effectiveness in children, in combination with other lithotripsy procedures it can reach very high rates of stone removal.

Newer machines with dual-frequency technology, real-time Ultrasound Imaging, automated ESWL capable of adjust the shock wave intensity and frequency in real-time are some innovations in ESWL that have improved the safety and efficacy of the procedure.

Recent advancements in ultrasound (US) technology are being developed to broaden its therapeutic uses. It includes ultrasonic propulsion and burst wave lithotripsy (BWL) for the treatment of kidney stones. In clinical and preclinical testing, these innovative, non-invasive uses have yielded encouraging outcomes.

As it begins trials shattering and evacuating kidney and urinary tract stones in the outpatient clinic, these continual advancements to present technology will enable capabilities to serve a broader patient group.

There are significant unknowns about the best candidates, therapy parameters, and eventual incorporation into clinical practice for both.

Another non-invasive option that is emerging in recent years is acoustic trapping through the radiation force of a field of acoustic wave. The radiation force is a result of the momentum transfer caused by wave scattering from an object placed in the wavefield.

Vortex beams are widely employed to generate an intensity well, which is a low-intensity zone surrounded by a high-intensity region that may trap and direct an object. Acoustic waves are generated by the vortex and move through the water, focusing on the stone and breaking it up into smaller pieces. The smaller stone particles are subsequently excreted from the body via the urine.

The gadget is intended to be very accurate and effective while causing minimum negative effects. Because the therapy is non-invasive, it may be conducted as an outpatient procedure, and patients are usually not sedated.

Larger stones that may be difficult to cure with other non-invasive procedures, such as extracorporeal shock wave lithotripsy (ESWL), benefit most from the therapy.

Overall, vortex wave lithotripsy is a potential new therapy option for kidney stones that is both safe and effective. While it is still in its early stages, investigations have indicated that it is very successful and may have various advantages over existing non-invasive kidney stone therapies.

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URINARY LITHIASIS AND EXTRACORPOREAL SHOCK WAVE LITHOTRIPSY: NEW APPROACHMENTS

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JUSTIFICATION

The efficacy and the minimization of potential adverse effects are areas in which ESWL might be improved. Higher success rates and improved stone fragmentation may result from new lithotripter designs, advancements in shock wave production and delivery, contactless particle manipulation and ultrasound technology.

HYPOTHESIS

To prevent the mobility of the calculus and impacting of shock waves in the renal tissue, is presented the vortex beams. Vortex beams can be modulated in intensity, phase, repetition rate, topological load according to the size, irregularly shape, and composition of the mass to be destroyed. Besides, they generate shear stress very efficiently.

Burst Wave Lithotripsy employs high-energy shock waves to shatter the stones into tiny fragments. Combined with ultrasonic propulsion, stones may be transported through the urinary system more readily. .

OBJECTIVES

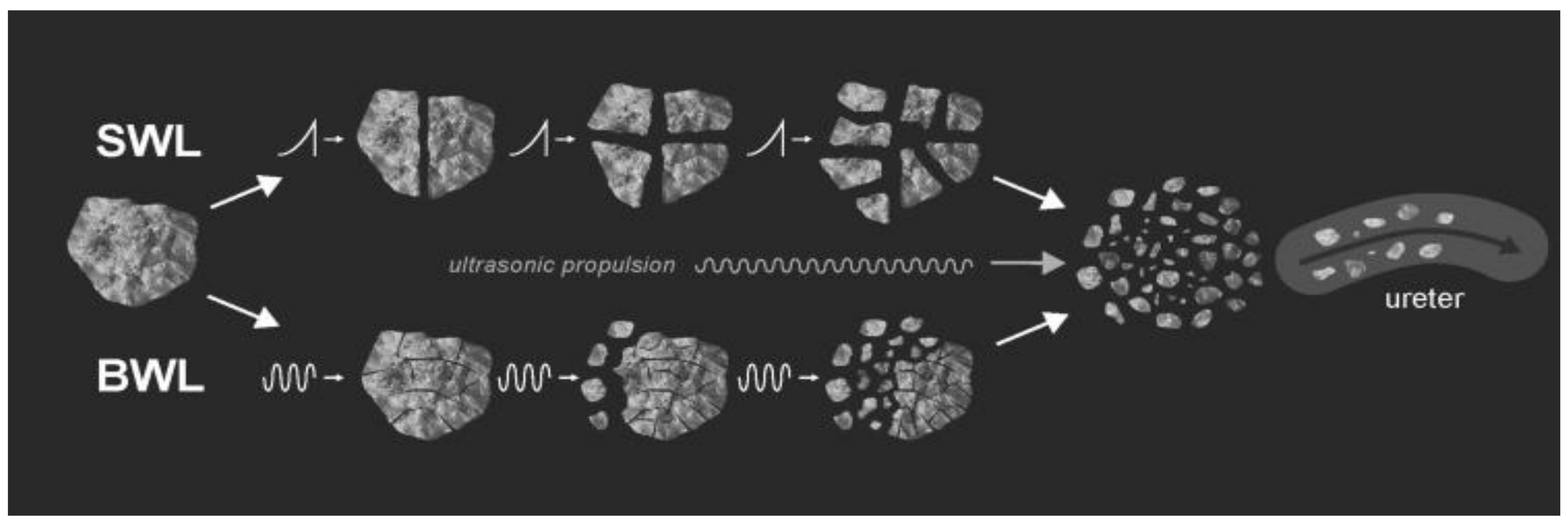
Conduct a complete and structured analysis of the most current extracorporeal lithotripsy systems in the management of kidney stones, and collect and evaluate the complications associated with using conventional ones

RESULTS

Current extracorporeal lithotripsy systems

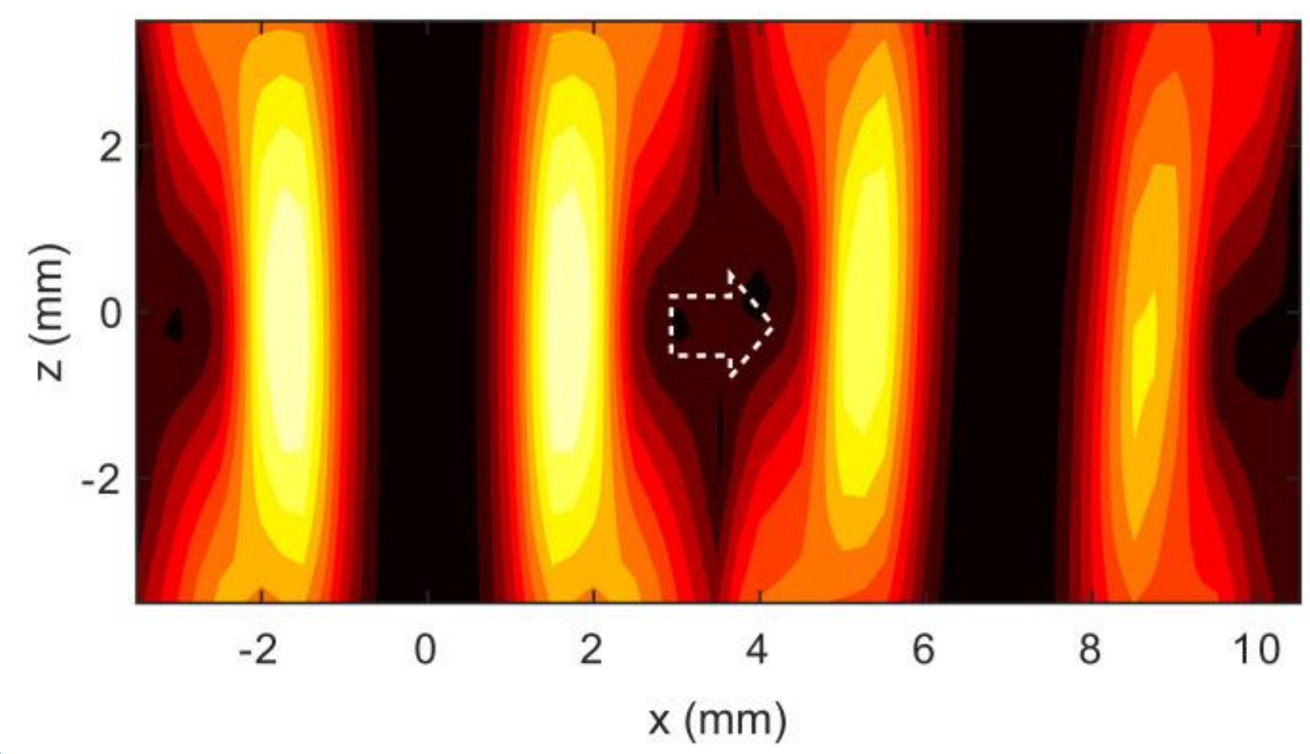
Burst wave lithotripsy (BWL) is an alternative to SWL. BWL has different physical characteristics than SWL in that it has a lower pressure and a higher frequency.

When BWL is used in conjunction with ultrasonic propulsion, there seems to be a synergistic impact on fragmentation efficacy.



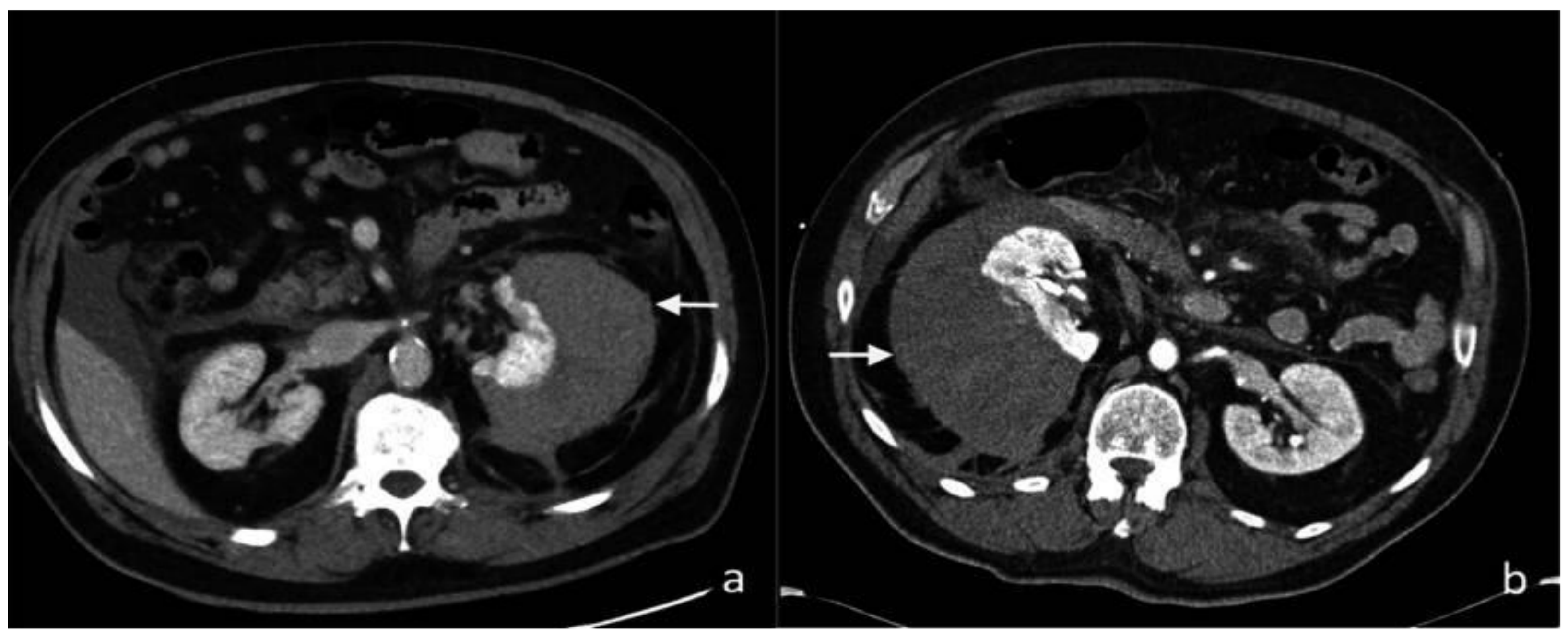
Since vortex beams generate shear stress more efficiently, the ultrasonic field amplitudes required for fragment computations are substantially smaller than in existing extracorporeal shock wave lithotripsy approaches

Bubble cavitation and shear stress have been demonstrated to play an essential role in the mechanical trauma induced by the shock wave. The presented technique also reduces the negative effects on the soft tissues that surround the solid.



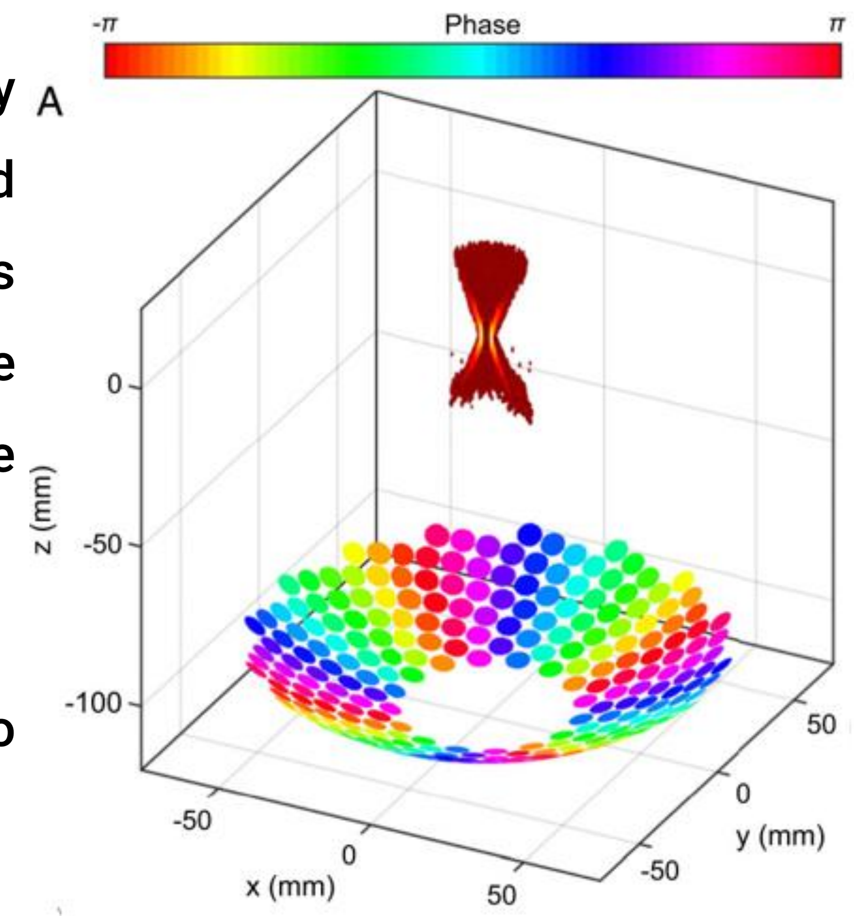
Extracorporeal shock wave lithotripsy. Complications

SWL is not completely innocuous and there can be injury to the kidney. Although extracorporeal SWL is noninvasive and the main force of shock wave energy is focused on the stone, the surrounding renal parenchyma is also subjected to trauma.



CONCLUSION.

- Vortex beams generate an intensity well, allowing objects to be trapped and excreted. Acoustic waves generated by the vortex breaks stone into smaller pieces, that are subsequently excreted via the urine.



- Larger stones that may be difficult to cure benefit from acoustic therapy.
- Non-invasive therapy with minimal negative effects, performed as outpatient procedure, and patients are usually not sedated.
- Vortex wave lithotripsy is a safe and effective therapy for kidney stones. It is still in its early stages but investigations have indicated that may have various advantages over existing non-invasive kidney stone therapies.