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MINIREVIEWS

Strategies to optimize shock wave lithotripsy outcome: Patient selection and treatment parameters

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Abstract

Shock wave lithotripsy (SWL) was introduced in 1980, modernizing the treatment of upper urinary tract stones, and quickly became the most commonly utilized technique to treat kidney stones. Over the past 5-10 years, however, use of SWL has been declining because it is not as reliably effective as more modern technology. SWL success rates vary considerably and there is abundant literature predicting outcome based on patient- and stone-specific parameters. Herein we discuss the ways to optimize SWL outcomes by reviewing proper patient selection utilizing stone characteristics and patient features. Stone size, number, location, density, composition, and patient body habitus and renal anatomy are all discussed. We also review the technical parameters during SWL that can be controlled to improve results further, including type of anesthesia, coupling, shock wave rate, focal zones, pressures, and active monitoring. Following these basic principles and selection criteria will help maximize success rate.

Key words: Shock wave lithotripsy; Kidney stones; Nephrolithiasis; Treatment outcome; Optimization

Core tip: Shock wave lithotripsy is a commonly utilized technology for kidney stone treatment that has declining efficacy over the past decade. The paper outlines how to optimize outcomes with proper patient selection and control of treatment parameters.

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INTRODUCTION

Shock wave lithotripsy (SWL) was introduced in 1980, modernizing the treatment of upper urinary tract stones. Prior to the SWL era, proximal ureteral and renal calculi required major operations with a prolonged recovery time. Because SWL is a non-invasive surgical procedure with a low complication rate allowing same day discharges, it has been the most commonly utilized treatment of kidney stones

Table 1 Stone criteria for shock wave lithotripsy

Sub-optimal features suggesting alternate therapy
Stone size > 2 cm
Multiple stones
Lower pole stone
Hounsfield unit > 1000
History of cystine, calcium oxalate monohydrate, matrix stones

over the past 3 decades[1-3]. Over the past 5-10 years, however, use of SWL has been declining and just recently, a group in Canada showed ureteroscopy has surpassed it as the most common treatment of nephrolithiasis[1-4]. While ureteroscopy is more invasive than SWL, it is still minimally invasive, with a low morbidity profile, and it is more reliably definitive than SWL requiring fewer subsequent procedures to establish stone-free status[5]. As SWL technology has transformed to a more convenient and easier process, success rates have declined. SWL outcomes, however, can be optimized with careful patient selection and control of specific treatment parameters. Herein, we review how to maximize the success rate of SWL and reduce failures by defining the appropriate range of uses and outlining what technical factors can be controlled to improve efficacy.

PATIENT SELECTION

Success rate of SWL varies considerably. This variability is a direct result of well-established stone-specific and patient-specific features. While the American Urological Association guidelines for management of ureteral calculi cite SWL as a primary treatment option if intervention is needed, and the technology could theoretically be used on any urinary stone, selectivity is crucial to maximize efficacy[6] .

Stones have varying responsiveness to SWL depending on several aspects. Stone size and number, location, density, and composition all affect the stone-free rate following SWL (Table 1). The American Urological Association Guideline on the management of staghorn calculi recommends against SWL as monotherapy because of poor outcomes, with only 54% overall stone-free rate, and increased complications (pain, obstruction, infection, bleeding, loss of kidney)[7]. SWL may be appropriate as an adjunctive procedure following percutaneous nephrolithotomy for staghorn calculi if there is a small residual stone. In general, it is still recommended that nephroscopy be the final procedure performed to confirm stone clearance in this setting[7]. If SWL is used as monotherapy for staghorn calculi, then a stent or nephrostomy tube should be placed prior to intervention, though the drainage mostly helps to prevent complications, and does not necessarily improve outcome. Multiple procedures are generally required for this scenario.

While staghorn is the extreme of large stone size, any stone over 2 cm is associated with an inferior outcome when treated with SWL[8-11]. Larger stones usually require more procedures and have increased complications such as obstruction from steinstrasse or larger fragment passage. If a stone is larger than 2 cm, then an alternate treatment may be best. In addition to stone size, total stone burden should be considered when electing treatment. If there are several stones throughout the kidney or bilateral stones amenable to single stage ureteroscopy *vs* multi-stage SWL then the patient should be counseled that stone-free rate may be higher with fewer procedures with the former option.

In addition to stone burden dispersed throughout the kidney making SWL less ideal, different stone locations affect success rates of the procedure. Specifically, there is an abundance of literature showing a lower stone-free rate for kidney calculi located in the lower pole treated with SWL with highest success rates in renal pelvic, upper pole and ureteropelvic junction stones[12-15]. Lower pole 1, a prospective, multicenter, randomized controlled trial evaluating treatment outcome for lower pole kidney stones, illustrated a 37% *vs* 95% stone-free rate for SWL *vs* percutaneous nephrolithotomy[12]. Outcome worsened further for lower pole kidney stones larger than 2 cm when treated with SWL (stone free rate 14%)[12]. This inferior outcome is directly related to the infundibulopelvic angle and lack of fragment clearance, rather than actual successful fragmentation. Success rates can be further delineated with measurements of infundibular width and length. One research group evaluated these anatomical features using intravenous pyelogram measurements and better stone clearance with SWL was achieved in kidneys with a wide infundibulopelvic angle or a short length and a broad width[15].

In addition to kidney stone locations, ureteral stone location affects outcome as well. Lower stone free rates are seen with distal ureteral stones, particularly stones greater than 1 cm, and SWL is not recommended as the primary treatment option but is an acceptable secondary alternative[6]. In general, SWL of the pelvis (distal ureteral stones) is avoided in women of childbearing age due to the theoretical risk of adjacent adnexal injury[6,16].

Both how hard a stone is and its composition also affect outcome of SWL. Density alone is a great predictor of successful fragmentation. Several groups have found that Hounsfield unit (HU) measurement of the stone on computed tomography imaging is associated with stone-free rate[17-19]. One group reported treatment failure in close to 50% of patients for stones great than 1000 HU[19]. Another study found at least 3 SWL sessions were required 70% of the time if HU was more than 750, and stone-free rate was still only 65%[18]. Specific stones compositions are more dense than others, and therefore have well-established resistance to SWL. Brushite, cystine, and

Table 2 Patient criteria for shock wave lithotripsy

Sub-optimal features suggesting alternate therapy
Obesity - skin to stone distance > 10 cm
Pelvic kidney
Horseshoe kidney
Calyceal diverticulum

Table 3 Absolute contraindications to shock wave lithotripsy

Anticoagulation
Bleeding diathesis
Pregnancy
Severe skeletal malformations
Distal obstruction
Infection associated with obstruction

calcium oxalate monohydrate are well-known to have very poor responses to SWL[7,20-24]. If suspicious for these stone compositions based on prior history or crystal presence on urinalysis, SWL is best avoided and another treatment selected. Matrix stones, while not dense, are made of organic matter and do not break with SWL[25]. Ureteroscopy or percutaneous nephrolithotomy should be used to treat this rare stone type if known.

Once the checklist for SWL has been reviewed for ideal stone characteristics, patient-specific features need to be evaluated. Body habitus and renal anatomy both affect SWL outcome (Table 2). Obesity, specifically skin to stone distance (SSD) measured on axial imaging, predicts outcome, with greater than 9 or 10 cm having a poor result[26-28]. This is because the shock wave fired loses energy as it travels through excess body fat in a patient with an elevated body mass index[29]. Pelvic kidneys and horseshoe kidneys also have a lower stone-free rate with a greater number of SWL sessions needed to achieve success[30,31]. SWL is generally not recommended in patients with a calculus in a calyceal diverticulum. While some patients may have symptomatic relief with stone fragmentation, stone-free rate is only 21% because the diverticular neck does not allow for stone passage[32]. If the ostium of the diverticulum is well-visualized, the stone is small, and the diverticula fills with contrast, success rates have been shown to be improved[33]. Hydronephrosis and renal insufficiency are also associated with lower success rates but the mechanism for this is unknown[34]. Anticoagulation, bleeding disorders, pregnancy, severe skeletal malformations, distal obstruction, and infection associated with obstruction are all absolute contraindications to SWL (Table 3)[6,35].

While some patients may still choose SWL despite not satisfying all criteria, keeping these general principles in mind regarding stone-specific characteristics and patient features when electing SWL will improve the procedure success rate.

Table 4 Technical factors that optimize shock wave lithotripsy outcome

General anesthesia
Optimal coupling
Low shock wave rate (60 shocks per minute)
Wider focal zone
Active intraoperative monitoring

TREATMENT PARAMETERS

Once SWL is selected as the procedure for definitive management based on the above criteria, several technical parameters during the procedure can be controlled to also optimize outcomes (Table 4).

The first way to improve outcome begins before the procedure even starts when selecting anesthesia. With more modern lithotripters having a narrow focal zone, unforeseen movements may shift the location of the stone out of the treatment zone, thus delivering shocks to surrounding tissue instead of the desired target. One way to minimize movement is to administer general anesthesia, as the anesthesiologist can control respirations with adjustments of rate and volume as needed, thus providing more control over kidney and stone motion. Several studies have shown improved SWL outcomes with higher stone free rates using general anesthesia *vs* sedation[36,37].

The next way to improve outcome is during the preparation. The original lithotripter in 1980 immersed patients completely in a bathtub and therefore used water as the medium to couple the shock wave to the patient. This was the optimal coupler as there was no air present to dissipate any energy. With miniaturization of the technology, most lithotripter machines now have a dry treatment head and use gel or oil for coupling. This has negatively impacted the outcome as air bubbles that form within the medium dampen the energy and reduce the impact on the stone. Efficacy can be reduced by as much as 40% with the presence of as few as 2% of air pockets[38]. Avoiding patient movement or repositioning during the procedure will lessen the impact of this effect minimizing the number of air pockets created. Additionally, medium application as a large volume mound directly from the stock container has been shown to minimize air bubble creation far more than dispensing from a squirt bottle or applying with the hand[39].

Once ready to initiate SWL several settings can be adjusted as well to optimize outcome. Shock wave rate can be set prior to initiating treatment and a slow rate of 60 shocks per minute has been shown to not only reduce tissue injury but also have a superior stone free rates[40-45]. This optimal rate has been confirmed by several studies including a meta-analysis of randomized controlled trials[46]. If the lithotripter being used, allows for control of focal zone size and pressures, a wider zone with lower pressures have been shown to have the best outcomes while reducing tissue injury[47-50]. Another setting recommendation for SWL is pre-treating the stone at a low energy for 100-200 shock waves and then pausing for several minutes prior to going to a higher energy[50,51]. While this does not necessarily improve efficacy of SWL it does improve outcome by decreasing injury to the kidney[52-54]. Once the procedure begins, active monitoring of the stone location with continuous ultrasound or spot fluoroscopy every couple of minutes or every 100-200 shocks, will confirm that the target is still appropriately positioned within the treatment zone.

Following these general guidelines for control of technical parameters during SWL will help to optimize outcome and improve stone free rates while minimizing tissue injury.

CONCLUSION

SWL is an excellent treatment modality for upper urinary tract treatment stones however success rate has decreased in the recent years secondary to changes in the machine design. Careful patient and stone selection and control of technical parameters improves stone free rates and will more likely result in a successful outcome.

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