

A Comparison of Treatment Modalities in Renal and Ureteral Calculi

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How to cite this paper: Trew, J. and Cornfield, J. (2017) A Comparison of Treatment Modalities in Renal and Ureteral Calculi. *Open Journal of Urology*, 7, 47-53.
<https://doi.org/10.4236/oju.2017.73007>

Received: January 17, 2017

Accepted: March 13, 2017

Published: March 16, 2017

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Abstract

In the decades, since the advent of shockwave lithotripsy, instrumentation and techniques in both ureteroscopic and percutaneous stone management have improved exponentially, leading to both increased success and lower complication rates. As a result, there have been some controversies revolving around the therapeutic modality of choice for specific stones in terms of their size and location. This review seeks to provide some clarity to the decision-making process with emphasis on patient comfort and choice and due consideration being given to the potential complications associated with the various treatment modalities.

Keywords

Shockwave Lithotripsy, Ureteroscopy, Percutaneous Nephrostolithotomy

1. Introduction

Multiple minimally invasive surgical treatment modalities for renal and ureteral calculi have become the treatment of choice beyond traditional open techniques. These relatively less invasive treatments for upper tract stones include shock wave lithotripsy (SWL), ureteroscopy (URS), and percutaneous nephrostolithotomy (PCNL). Treatment controversy often centers on optimal treatment selection. Ideally, treatment should be individualized and dependent on calculi size, location, composition, treatment availability, and the treating physician's experience. Each treatment carries with its own unique set of potential complications, and risk vs. benefit must be considered regarding procedure selection in each patient. The aim of this review is to discuss the various treatment options in light of the current 2016 AUA Guidelines [1] analyze current literature and evidence regarding safety and efficacy amongst SWL, URS, and PCNL.

2. Methods of Treatment for Stone Removal

Extracorporeal Shock Wave Lithotripsy

The National Kidney Foundation describes SWL as the most commonly utilized method for treatment of all stones in the upper tract; however, SWL finds its greatest utility in renal and proximal ureteral stones. SWL is regarded as an outpatient procedure that generally requires some form of anesthesia. During SWL, high energy shock waves of varying strengths produced by an external self-contained generator of some types (percussive, magnetic or piezoelectric) are focused on the stone as a method of delivering enough kinetic energy to cause stone fragmentation secondary to repeated directed circumferential stressors of the crystal's chemical bonds. The resultant fragmented products are generally small enough to pass spontaneously through the ureter without leading to obstruction and thereby become subject to elimination during the normal course of micturition. Two to three thousand shock waves are generally all that is required to fragment a stone. If larger stone fragments persist, the patient may require additional SWL, or the use of some other surgical methodology, such as URS, in order to effectuate complete stone removal. Patients tend to prefer SWL initially because of the relatively non-invasive and painless nature of the procedure.

SWL is ideal for uncomplicated solitary renal stones of 1.5 cm or less or ureteral stones of approximately 1 cm or less or an estimated combined stone burden of less than 2 cm on KUB. There are, however, stone compositions that tend to be more resistant to SWL, making these stones more likely to require ancillary treatment. These compositions include some very dense calcium oxalate monohydrate stones, brushite stones, and a sub-type of cysteine stones [2]. Because fluoroscopic imaging is utilized during the vast majority of SWL procedures, and because shockwaves can theoretically damage fetal lung or brain tissue, pregnancy is an absolute contraindication to SWL. Other poor candidates for this method include patients with bleeding disorders (either intrinsic or due to medications), infections, structural renal abnormalities, or those who are morbidly obese, generally meaning a BMI greater than 50 [3].

As with all procedures, there are potential risks associated with SWL. About 10% to 15% of patients may not have their calculi broken into small enough pieces to easily pass through the urinary tract on their own, in which case, pieces may become lodged in the ureter (Steinstrasse) and require further treatments as mentioned above. SWL also has the potential to cause renal injury, leading to hematoma (usually sub-capsular) that can incite transient hypertension and, rarely, require transfusion or other intervention. Most often, these spontaneously resolve over time [2]. In 2008, McAteer and Evan reported on concerns expressed regarding the shock wave pressures as measured several centimeters away from targeted [2]. It has been hypothesized that nearby organs, such as the colon, duodenum in the case of the right kidney or pancreas in the case of the left might be the recipients of enough shock wave induced pressure that they may be subject to pressure induced by damage; however, as of this writing there have been no validating data that would support this [2].

Ureteroscopy

Ureteroscopy is also generally an outpatient procedure where a small caliber scope is passed through the bladder and into the ureter for purposes of direct visualization, diagnosis, and extraction or lithotripsy (via various forms of energy application) of ureteral, or even renal, stones. The surgeon may pass a basket into the ureter for removal of the stone in toto, or various devices (laser, electrohydraulic or pneumatic) may also be utilized in order to fragment larger, obstructed or impacted stones, the smaller particles of which are then allowed to pass spontaneously and the larger subject to basket extraction. URS is most commonly utilized as primary treatment for stones located at the distal half of the ureter, as salvage therapy for patients whose stones have failed SWL, or for patients with stones in the upper ureter or kidney who carry contraindications for SWL. Potential risks of URS include infection, bleeding, mucosal irritation and trauma to ureter including perforation or avulsion and late ureteral stricture formation [3].

Percutaneous Nephrostolithotomy

This procedure consists of the creation of a small incision or puncture in the lumbar region to allow access into the kidney where a nephroscope and small instruments may be utilized to directly pulverize the stone, generally via the use of laser or ultrasonic lithotripsy, in order to facilitate extraction. Most authors regard PCNL as the treatment of choice for stones larger than 2 cm, irregularly shaped stones, and history of failed attempts at other methods, and in patients who are poor candidates for URS or SWL. The goal is swift removal of calculi with the desired end point being that no fragments are left to pass through the urinary tract. Potential risks include retained fragments, infection, bleeding (which may be profound), and injury to nearby organs [3].

3. Data Based on Stone Location

Renal and Proximal Ureter

Due to a historically lower success rate of SWL, treatment for renal stones in the lower pole has become somewhat controversial over time. Treatment modalities consist of expectant management for asymptomatic stones or any of the various active methods previously mentioned, SWL, URS, and PCNL. PCNL may be preferred for larger stones, >1.5 - 2 cm, due to a higher stone-free rate but at a cost of higher morbidity. Stones smaller than the 1.5 to 2 cm threshold are more frequently managed with SWL or URS, however, the most efficacious modality is still a subject of debate.

El-Nahas AR, *et al.* [4] retrospectively analyzed treatment success for stones ranging from 1 - 2 cm with either SWL or URS with laser lithotripsy. They reported on 37 patients who underwent URS and 62 who completed SWL. The stone-free rate after three months was 86.5% and 67.7% respectively, with three URS patients requiring additional treatment with SWL for stone clearance and five SWL patients requiring URS. Complication rates were 13.5% for URS and 4.8% for SWL, however because of the low numbers of study participants, the differences in complication rate did not reach statistical significance, with a P =

0.146. Based on this URS might be favored for lower pole stones due to the higher stone-free rate, at the risk however, of a much larger complication rate, as was evident in these patients [4].

Size of proximal ureteral stones is a primary indicator of treatment modality success. Kumar, *et al.* [5] undertook a prospective randomized trial which followed 180 patients with a single, radiopaque stone located in the upper half of the ureter with size <2 cm. These patients were treated with either SWL (90 patients) or URS with holmium laser (90 patients). Mean stone size for both modalities was approximately 1.2 cm. When evaluating three-month stone-free rates of size less than 1 cm, SWL's stone-free rate was comparable to URS at 84.9% and 87.7% respectively ($P = 0.32$). For stones 1 - 2 cm, SWL's stone-free rate was 78.4% and URS was 85.4% ($P = 0.12$), demonstrating SWL's mildly reduced effectiveness with increased size of stone. The complication rate for all stones was 6.6% with SWL and 11.1% with URS ($P = 0.21$), once again showing an increased, but not quite statistically significant, risk of complications with URS [5].

Khalil M., [6] undertook an additional study which compared 82 patients suffering from a single, impacted, radiopaque stone <2 cm in the proximal half of the ureter that had remained unchanged for a minimum of 2 months. These patients were treated with either SWL (37 patients, max of 3000 shocks each) or URS with laser (45 patients). Effectiveness at three months was comparable with stone-free rate of 78.4% using SWL and 82.2% using URS. Five SWL patients needed retreatment, while three patients required a third treatment before becoming stone-free. Eight SWL patients failed stone fragmentation altogether, resulting in five patients who subsequently underwent URS and three who subsequently underwent laparoscopic ureterolithotomy. Complications reported with SWL patients were similar to previous studies which included hematuria in six patients and a febrile UTI in one patient. In six URS cases, SWL was needed as an adjunct for successful management of retained fragments. More serious complications were seen in URS, as three patients developed what were described as small ureteral perforations, resulting in prolonged double-J stent placements [6].

Distal Ureter

First line treatment for distal ureteral stones is less controversial with URS being the treatment of choice due to its relative safety and much higher efficacy. Verze P., *et al.* [7] conducted a prospective randomized study wherein 273 patients with solitary, unilateral, radiopaque, distal ureteric stones with a stone size of 0.5 - 1.5 cm and requiring intervention were enrolled into two different treatment arms-either SWL (137 patients) or URS (136 patients) [7]. Distal ureteral stones were defined as stones located in the "segment between the lower border of the sacroiliac joint and the ureterovesical junction". SWL was set at frequency of 120 shocks/min and mean number of shockwaves delivered was 3200. For patients who underwent URS, laser treatment may have been utilized along with basket or forceps for assisted extraction. Treatment failure was defined as the inability to render the patient stone-free within three months following the initial treatment. In those who underwent SWL, 92.70% become stone-free. In

55.11% of cases, one SWL treatment was sufficient for complete clearance. In 31.49% of cases, two SWL treatments were required for stone clearance, and in 13.38%, three treatments were needed for complete clearance. All SWL treatments requiring repeated treatment were of stones with diameter greater than 1 cm. Fourteen cases had postoperative complications of obstructive pyelonephritis resulting in stent placement [6].

In patients who underwent URS, 27 with stones less than 1 cm had the stones extracted without fragmentation, and intracorporeal lithotripsy was required for the remaining URS cases (109). Stone-free rate was 94.85% with ten patients requiring repeat URS as a result of submucosal dissection in five cases and inability to properly dilate the ureteral orifice in five cases. Complications also included ureteric perforation in one patient as well as postoperative hemorrhage in seven cases. URS failure occurred therefore in 5.14% of cases [7].

Aboumarzouk OM, *et al.* [8] conducted a study which demonstrated similar results and concluded that URS was superior in regards to three-month stone-free rates, but at a higher complication rate and longer hospital stay. This study also reported significantly higher instances of retreatment with SWL therapy to achieve stone clearance, however, SWL therapy was less likely to need ancillary treatment than URS [8].

4. Discussion

The decision-making process as regards the optimal treatment modality for a particular patient's stone burden must take into account multiple factors and treatment should be individualized. The data presented above does reveal clear trends as reflected in the 2016 AUA Guidelines for the Surgical Management of Stones. The preferred treatment modality for particular stones based on size and location is summarized alongside each modality's associated potential complications in **Table 1**, below.

Table 1. Summary of preferred primary therapy & associated potential complications.

Stone Size	Therapy	Potential Complication
Renal Stones		
<1 - 1.5 cm	SWL	Inadequate fragmentation, retained fragments renal Injury, hematuria, transient hypertension
1.5 - 2.0 cm	URS/SWL	
>2.0 cm	PCNL	Inadequate fragmentation, retained fragments bleeding, damage other organs (lung, colon, spleen, pancreas)
Ureteral Stones		
Upper Ureter		
<1 cm	SWL	
>1 cm	URS	Infection, bleeding, mucosal irritation ureteral perforation or avulsion, retained and/or migrated fragments, ureteral stricture formation
Lower	All	URS
		As above

Renal Stones <1 cm to 1.5, even those in the lower pole, should be managed with SWL as first-line therapy, with the caveat that in the lower pole URS may offer a higher stone free rate in a single setting but with a marginally higher complication rate. Renal Stones >1.5 cm - 2.0 cm are generally better managed via URS or PCNL, while Renal Stones >2.0 cm are generally best managed via PCNL.

Upper Ureteral Stones up to 1 cm in size may be managed with equal efficacy via SWL or URS while Upper Ureteral Stones >1 cm in size are most efficiently dealt with using URS, the higher complication rate notwithstanding.

Lower Ureteral Stones are best dealt with using URS, although SWL may be utilized in certain circumstances with the caveat that multiple courses of therapy may be required.

The studies quoted demonstrated that stone-free rates with SWL were inversely proportional to stone size, leaving it more likely to require retreatment for larger stones. Most cases were successful after retreatment, often not needing ancillary treatment.

Complication rates were somewhat higher and often more severe with URS. The common complications reported by patients with SWL in these studies included hematuria, UTI, pyelonephritis, and pain. Complications reported for URS included ureteral perforation, even disruption, and hemorrhage, often prolonging an already extended hospital stay and creating the need for more profound intervention.

5. Conclusion

In conclusion, stones of 1 to 1.5 cm or less in diameter may undergo initial optimal treatment with SWL as clearance rates are comparable to URS in the upper ureter and kidney. In addition, there are less frequent and less serious complications, making SWL superior to URS for stones in this size. Once a stone surpasses 1 cm in diameter, decision making becomes more complicated as URS demonstrates slightly more efficacy. A modest increase in efficacy does not mean that URS for stones 1 - 2 cm is ideal in all circumstances. Consideration for lithotripsy, including its availability and the urologist's personal experience is important, as well as the patient's understanding and preferences.

While higher stone-free rates and fewer retreatments are evident using URS for stones 1 - 2 cm, a provider and patient must discuss the increased risk of potentially severe complications before decisions are made. For stones 1 - 2 cm, patients may prefer SWL initially because it is less invasive with infrequent complications. If unsuccessful, it may seem reasonable to the patient to move on to retreatment or a more invasive procedure such as URS after exhausting safer options. If stones are located more distally in the ureter, SWL is less favored as retreatments are more frequent, particularly with larger, distal stones. Complete stone removal is more likely using URS for these distally located stones with relatively few complications.

As always, patient's past medical history, comorbidities, pre-existing risk factors, and lifestyle must be considered as these may sway modality selection one

way or another. All in all, urologists can utilize this data to make the optimal selection for their individual patient, as each case is unique.

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Abbreviations

SWL—Shockwave Lithotripsy

URS—Ureteroscopy

PCNL—Percutaneous Nephrostolithotomy

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