Current evaluation and management of renal and ureteral stones

Matthew T. Gettman, *MD,* ***Joseph W. Segura,*** *MD.*

ABSTRACT

A systematic clinical approach is required for the diagnosis and management of renal and ureteral stones. The presenting symptoms, past medical history, medications, and physical examination all provide clues to the diagnosis of urinary stones. In the acute setting, noncontrast helical computerized tomography has emerged as the first line imaging test for renal colic. More traditional imaging tests are also important in the management of stone disease. After making the diagnosis of a urinary stone, the urologist should discuss the advantages and disadvantages of all treatment options with the patient. For most stone patients today, many equally effective treatment approaches can exist for the same problem. To help direct surgical management, guidelines for stone management have been devised. With technologic advances, stone treatment has improved and complications have decreased. While patient care has been significantly impacted by use of effective endourologic techniques, patients should complete imaging tests following surgery to assure a stone-free state. In addition, recurrent stone formers should complete a medical stone evaluation to identify treatable causes of their stones.

Keywords: Uteroscopy, percutaneous ultrasonic lithotripsy, shockwave lithotripsy, surgical treatment, renal calculus, staghorn calculus, ureteral calculus.

Saudi Medical Journal 2001; Vol. 22 (4): 306-314

Despite ongoing clinical advances, urinary stones remain a major medical problem in our population. The evaluation and management of urinary stones has radically changed in recent years.[1-7] At the same time, understanding of urinary stone pathogenesis has evolved to aid in the prevention of stones. Throughout the United States and in other areas of the world, urinary stone development is dependent not only on medical issues but also on environmental factors.[8-10] While these issues ultimately influence the treatment and prevention of urinary calculi, such ideas are far from the minds of patients presenting with an acute stone crisis. Today, the evaluation of stones is based on history and physical examination, laboratory testing, and radiographic imaging.[2-6] Treatment of urinary stones is based on the application of advanced technology and the use of endourologic techniques. While the tremendous advances in stone evaluation and management have had a positive impact on patient care; areas of controversy remain, especially in light of the ever-changing technology. Indeed, in the current era, many equally effective options exist for the evaluation and treatment of urinary calculi. In this review, we describe the current evaluation and management of renal and ureteral stones.

Clinical presentation and evaluation. Multiple clinical presentations can exist for renal and ureteral stones, however the majority of patients report symptoms of classic renal colic, flank pain, or irritative voiding.[2-6] The majority of urinary stones are calcium-based, however, in certain subsets of the population and in specific geographical areas throughout the world, patients are predisposed to other types of urinary stones (Table 1).[2-6] The pathogenesis of specific types of urinary stones has been previously described in detail.[2-11] Ureteral stones are generally thought to form proximally in

From the Department of Urology, Mayo Clinic, Rochester, MN, United States of America.

Address correspondence and reprint request to: Dr. Joseph W. Segura, Department of Urology, Mayo Clinic Rochester, 200 First Street SW, Rochester, MN 55901. Tel. +1 (507) 2842511. Fax. +1 (507) 2844951. E-mail: segura.joseph@mayo.edu

Table 1 - Comparison of more common urinary stones.

Composition	Incidence	Density	Appearance on plain x-ray	urine pH	Other
1. Calcium	70-80%				multiple factors in pathogenesis
Phosphate		+++++	very opaque	variable	
Oxalate		++++	opaque		
2. Struvite	10-20%	+++	moderately opaque, commonly staghorn	basic	"coffin-lid" crystals in urine
3. Cystine	1-5%	++	slightly opaque, ground glass appearance	acidic	autosomal recessive inheritance
4. Uric Acid	5-10%	+	radiolucent	acidic	humans lack hepatic uricase enzyme

the kidney and cause a variety of clinical systems during migration towards the bladder. Renal stones can involve select calyces or extensively branch to fill multiple calyces and the renal pelvis. The latter type of stone is often referred to as a staghorn calculus. Staghorn calculi are commonly composed of struvite or infection stone; however, uric acid, cystine, and very rarely, calcium stones can present in this configuration. Presenting symptoms help approximate stone location. In general, more patients are symptomatic from ureteral stones than renal stones. For instance, stones located in the distal ureter or at the ureterovesical junction are frequently associated with urinary frequency, stranguria, urgency, and sometimes even urge incontinence. Stones located in the upper or middle ureter often present with classic symptoms of renal colic. The sharp, wave-like, spasmotic flank pain of renal colic is commonly the end result of increased ureteral peristalsis in conjunction with a degree of ureteral blockage. Patients with classic renal colic frequently describe radiation of pain into the lower back or groin. Nausea and vomiting secondary to peritoneal inflammation are not rarely associated with stones. In some instances, however, the presence of a stone may be completely asymptomatic. A detailed review of the past medical history, past surgical history, and medications is necessary. Frequently, this information will provide important diagnostic information and clues to the stone pathogenesis. For instance, a patient with chronic dehydration secondary to chronic diarrhea or an ileostomy is frequently at increased risk for uric acid stones. Struvite stones are more common in women with flank pain and a history of recurrent urinary tract infections. In some instances, the medication history can provide very specific clues to a possible stone diagnosis. For instance, the presentation of renal colic in a human immunodeficiency virus patient on protease inhibitors would suggest the possibility of indinavir calculi.[11] Development of flank pain in a middle-aged hypertensive patient on triamterene could suggest a stone secondary to those crystals, however a diagnosis of a calcium stone would still be more likely. In laxative abusers, analysis of the urine can classically show ammonium urate crystals. The differential diagnosis for renal colic and flank pain is extensive. The accurate diagnosis of the urinary stones is quite important, as the mimics of renal colic can often represent more substantial and possibly, life-threatening situations (Table 2).[2-6] For instance, a patient with a dissecting thoracic aneurysm or symptomatic abdominal aortic aneurysm can present with symptoms of renal colic or flank pain. Also, development of right lower quadrant pain could

Table 2 - Differential diagnosis of urinary stone pain.

Cutaneous	Herpes zoster
Cardiac	Angina, Myocardial infarction
Pulmonary	Lower lobe pneumonia, empyema, infarction
Gastrointestinal	Acute cholecystitis, gastroenteritis, gastritis, PUD, colitis, appendicitis, hepatitis, bowel obstruction, tumor, pancreatitis, diverticulitis, incarcerated hernia
Urinary	Acute pyelonephritis, acute cystitis, blood clot, tumor, sloughed papilla, fungus ball, acute epididymitis, testicular torsion, testicular tumor
Reproductive	Acute salpingitis, ectopic pregnancy, ovarian cyst, tuboovarian abscess, mittelschmerz, endometriosis
Vascular	Aortic aneurysm, aortic dissection

represent a urinary stone, however in the right clinical situation, an appendicitis must also be considered. Eskelinen et al prospectively analyzed 1333 patients evaluated for acute abdominal pain. For the 59 patients initially diagnosed as having acute renal colic, 81% were noted to have the correct diagnosis. In only 9 other patients, the correct diagnosis of acute renal colic was missed at presentation.[12] Therefore, despite the occasional pitfalls, history and physical examination continue to play an important role in stone management. The physical examination frequently suggests the diagnosis of urinary calculi thereby guiding the radiologic assessment and laboratory evaluation. All patients undergoing an evaluation for urinary stones should have vital signs completed and an assessment of general well-being. A physical examination tailored to the genitourinary, gastrointestinal, and reproductive system is completed. Classically, patients with renal colic will have significant costovertebral angle tenderness and the stone diagnosis is confirmed with diagnostic tests. Laboratory tests are very helpful in the diagnosis and management of urinary stones. All patients routinely should complete a urinalysis and Gram stain or culture. Most patients with stones will have at least microscopic hematuria; however, depending on the clinical scenario, a stone can be present without hematuria. Additionally, the urinalysis provides important information regarding the urine pH and presence of bacterial infection. Microscopic assessment of the urine is equally important, as this evaluation can provide important clues to the diagnosis of urinary calculi. For instance, the presence of hexagonal crystals in the urine sediment of a young child with acidic urine, suggests a diagnosis of cystine stones. Furthermore, presence of coffin-lid shaped crystals in the urine sediment of a middle-aged female with recurrent urinary tract infections and alkaline urine would suggest a diagnosis of struvite stones. For patients with pyuria or bacteriuria, or both, assessment of the white blood cells is needed to exclude systemic infection. In addition, an electrolyte panel is commonly obtained to assess renal function. Use of noncontrast, helical computerized tomography (CT) has become the recommended initial test for evaluating acute flank pain.[13-17] Helical CT is less invasive and less risky than excretory urography and provides a more thorough assessment of the abdomen and retroperitoneum. Helical CT is more sensitive than both excretory urography and conventional CT, and helical CT allows for use of overlapping image reconstruction that facilitates precise identification of even small ureteral calculi. Helical CT also incorporates rapid image acquisition techniques to limit respiratory artifact. With noncontrast helical CT, the diagnosis of obstruction relies on the presence of hydronephrosis and stranding of the perinephric fat.[18] In the emergency room setting, helical CT provides a rapid and accurate diagnosis for the patient with renal colic. Recently, stone composition has also been determined with noncontrast helical CT.[19,20] While diagnostic testing in the emergency room setting has evolved into a less invasive approach, frequently a "gold standard" test is warranted in the non-acute setting. For instance, excretory urography is very important in the preoperative planning of patients with complex urinary stones and is an effective test to exclude postoperative urinary obstruction. Retrograde pyelography at the time of surgery provides valuable knowledge of ureteral anatomy. In addition, retrograde pyelography and CT remain important tests for the evaluation of most radiolucent stones. Furthermore, plain radiographs, nephrotomograms, and ultrasound remain helpful tests in various clinical situations. After completing the assessment of the patient and making the diagnosis of a urinary stone, the decision making process depends on many factors including patient age, body habitus, stone diameter, stone location, perceived stone composition, presenting symptoms, prior stone history, and patient anatomy. Symptomatic renal stones for the most part are treated on more of an elective basis, while ureteral stones more commonly prompt an emergency room evaluation. Indeed, if the patient is diabetic, looks ill, has a positive urine gram stain or culture, or has evidence of urinary obstruction, then urgent intervention is warranted. Other patients that require immediate intervention include patients with ureteral obstruction of a solitary kidney and bilateral complete ureteral obstruction with anuria. Many patients with an imperative need for treatment are initially managed with temporary drainage; however, in the right clinical situation definitive treatment is not unreasonable. Temporary drainage is completed with cystoscopy and stent placement or percutaneous nephrostomy tube drainage. Traditionally, the favored way to decompress the upper tract was percutaneous urinary drainage. In a study by Pearle et al, cystoscopic stent placement and percutaneous nephrostomy both effectively relieved obstruction due to infected ureteral calculi and neither treatment demonstrated superiority in promoting a more rapid recovery after drainage.[21] After undergoing upper tract decompression, patients are monitored for signs or symptoms of sepsis and treated with broad-spectrum antibiotics until the culture results are obtained. After the infection has been adequately treated, these patients then undergo definitive surgical treatment. For patients with unrelenting renal colic, hospitalization for pain control and definitive treatment of the ureteral stone is warranted. Uninfected patients with moderate symptoms of renal colic are frequently given a period of time for spontaneous passage of the ureteral stone. Stone size and location are helpful in determining the probability of spontaneous stone passage. In the series of 520 patients, Ueno et al evaluated the frequency of spontaneous stone passage. For a stone diameter of <4 mm, 4-6 mm, and >6 mm, spontaneous stone passage was observed 80%, 59%, and 21% of the time. The overall spontaneous stone passage rate was 55%.[22] In a meta-analysis of 6 series of patients, Hubner et al reported an overall spontaneous stone passage rate of 38% in 2704 patients. They noted 57% of stones < 4 mm spontaneously passed. The observation period and time to intervention among the 6 series included in the meta-analysis was variable.[23] Segura et al also completed a meta-analysis of 327 articles with acceptable outcome data.[24] For stones < 5 mm in diameter in the proximal ureter the spontaneous passage rate was 29-98%, whereas a rate of 71-98% was reported for the same sized stones in the distal ureter. Spontaneous passage for 5-10 mm stones was 10-53% in the proximal ureter and 25-53% in the distal ureter. Conservative ureteral stone management is abandoned in the presence of the following: new evidence of infection or obstruction, intractable pain, inability to pass the stone, and for socioeconomic reasons. Furthermore, as stone treatment has become relatively easier to perform and less invasive for the patient, enthusiasm for a conservative approach to symptomatic stone disease has dwindled. The surgical goals include complete removal of the stone burden, reversal of presenting complaints, and preservation of renal function.

Management of renal and proximal ureteral stones. Surgical options for upper tract stones include extracorporeal shock wave lithotripsy (SWL), percutaneous nephrolithotomy (PL), ureteroscopy (URS) with nephrolithotomy, combination treatments, or open surgery. Advantages and disadvantages exist for each treatment thus surgical management of renal and proximal ureteral stones must be tailored to the individual patient. First line treatment for most renal stones < 2.5 cm in diameter is SWL, however the recommendation depends somewhat on the lithotripsy device as well as other patient and technical factors. Optimal treatment of lower pole renal stones (SWL, URS, or PL) is currently under investigation. The American Urological Association (AUA) has devised specific guidelines for management of staghorn stones.[25] According to the guidelines, newly diagnosed staghorn stones require active treatment. All treatment options must be discussed in detail with the patient. As a guideline, PL followed by SWL or repeat PL should be used for most patients with a standard staghorn calculus. As a guideline, neither SWL monotherapy nor open surgery should be considered first-line treatment for staghorns in most standard patients. As options, PL and SWL are equally effective in treating small-volume staghorns when the renal anatomy is normal or near normal. Also as an option, open surgery is appropriate therapy when the stone cannot be treated effectively by PL or SWL. Nephrectomy is a reasonable option for a poorly functioning kidney bearing a staghorn stone. The recommended AUA guidelines were also reported as the most cost-effective methods for treatment of staghorn stones in a previous investigation.[26] The American Urological Association guidelines have also been established for proximal ureteral stones.[24] As a guideline, stones likely to pass can be placed on observation therapy with periodic evaluation. For all other stones, definitive treatment is recommended. Placement of a ureteral stent to facilitate stone fragment passage after SWL should not be routinely used to increase stone-free rates. First line therapy for stones < 1.0 cm in the proximal ureter is SWL. Percutaneous nephrolithotomy or URS are used for salvage treatment or if SWL is contraindicated. For stones > 1.0 cm in the proximal ureter, SWL, PL, and URS are all acceptable treatments.

Percutaneous surgery. Percutaneous nephrolithotomy is completed after the collecting system is entered through the flank, the percutaneous tract is developed over a guidewire, and a rigid nephroscope is introduced for stone visualization.[4] Percutaneous nephrolithotomy is usually completed in conjunction with an ultrasonic probe for stone fragmentation. Renal stones and proximal ureteral stones can sometimes be removed intact. For staghorn stones or multiple renal stones effectiveness of PL is sometimes limited by the intrarenal anatomy of the patient, however this is less of an issue in the era of flexible nephroscopy. Additional percutaneous tracts are sometimes needed to remove the entire stone burden. In general, if more than 2 or 3 tracts are needed for a stone-free state, then an alternative treatment plan should be devised.[4] At the completion of PL, the entire collecting system should be inspected to assure the patient is stone-free. Postoperative imaging studies should also be obtained to exclude residual stones.[27] Not rarely, residual stones will be discovered on the basis of radiographic studies that warrant additional surgery. Overall, PL has been used to remove large volume stones with excellent stone-free results. In our experience we have found PL most effective for large staghorn calculi. Segura reviewed a 1000 cases of PL and noted an overall success rate of 98% for renal stones and 88% for ureteral stones.[28] Patterson et al specifically reported on 68 patients with 74 struvite stones treated by PL and followed for 3 years postoperatively. The overall stone-free rate initially was 91%. At 3 years 89% of patients discharged stone-free from the hospital remained stone-free, whereas 62% of patients who were initially not stone-free had recurrent stones.[29] In a large series of patients treated by Lee et al, an initial stone-free rate of 85% was reported for PL. Interestingly, at 6-month follow-up, the stone-free rate had actually increased to 92%.[30] Chibber et al recently noted a stone-free rate of 85% for patients treated in the SWL era.[31] For a select group of morbidly obese patients, results from PL were comparable to results for the general patient population.[32] As previously suggested, patients with multiple large renal pelvis, or calyceal stones are effectively treated with PL. Lingeman et al compared treatment with SWL to PL for non-staghorn renal stones with aggregate sizes up to 3.0 cm. For stone burdens < 1.0 cm, 1.0-2.0 cm, 2.0-3.0 cm, and >3.0 cm, PL yielded stone-free rates of 88%, 91%, 90%, and 75%; while SWL yielded stone-free rates of 77%, 75%, 43%, and 29%.[33] For large lower pole stones, Lingeman also reported higher overall stone-free rates with PL (90%) as opposed to SWL (59%). In a prospective, randomized study comparing PL and SWL for definitive treatment of lower pole renal stones, Lingemann et al noted that the 3 month stone-free rates for a stone 1.1-2.0 cm were 10% with SWL and 75% with PL.[34] For proximal ureteral stones, PL provides another effective treatment option. However, given the success of SWL and URS, routine PL for all proximal ureteral stones is not indicated. Indeed, PL is used for patients in which SWL is contraindicated or as a salvage procedure for upper tract stones. Netto et al retrospectively reviewed 145 patients undergoing either PL, SWL, or URS for proximal ureteral stones and noted stone-free rates of 100%, 95%, and 92%.[35] In other studies, stone-free rates of 96-100% are reported.[36,37] Percutaneous nephrolithotomy remains the most invasive of the minimally invasive treatments for stones. Complications from PL are related to either percutaneous access or to stone removal. While the complication rates related to stone removal with PL are similar to other endourology techniques, the complications related to percutaneous access are more varied and tend to be more significant.[28,29] Injury to a branch intrarenal artery is probably the most significant problem, however the incidence of this problem is <1%.[28] Despite routine preoperative antibiotic use, septic shock is a possibility after PL. The most likely cause of sepsis is introduction of infected fluid into the bloodstream during the procedure.

Lithotripsy. While SWL is the treatment of choice for most renal and proximal ureteral stones,[24,25] SWL monotherapy is not considered a first-line therapy for large staghorn stones, large non-staghorn stones, large cystine stones, and many large lower pole stones. Previous reports have noted overall stone-free rates of 22-67% for staghorn calculi, 29-77% for other renal stones stratified by size, and 57-96% for proximal ureteral stones.[33-41] In select situations, however, SWL monotherapy can provide excellent results for less standard stones. Factors influencing the success of SWL include not only stone burden but also stone location, intrarenal anatomy, choice of lithotripsy machine, and required ancillary procedures. Elbahnasy et al studied the role of lower pole anatomy on stone clearance after SWL.[42] They noted a narrow infundibulopelvic angle, a long infundibular length, and a narrow infundibular width were adverse predictors of stone passage after SWL.[42] Similar to the previous investigation by Lingeman et al comparing PL to SWL for lower pole stones,[34] Havel et al also studied treatment of lower pole stones and noted improved stone-free rates for PL as opposed to SWL for all stone sizes analyzed.[43] Choice of lithotripsy machine is another important variable, as treatment is frequently more efficacious with a Dornier HM3 than with a 2nd or 3rd generation machine. Stone burden and stone composition are paramount concerns in selecting SWL. Lam et al used computer-assisted techniques to estimate stone volume prior to SWL treatment of staghorns stones.[44] They found SWL monotherapy overall achieved a 51% stone-free rate, however for stones with a stone surface area of 500mm^2 or less (surface area corresponds roughly to the surface area of a 2.5 cm stone) the stone-free rates were similar to PL. As previously suggested by Lingemann et al, increasing stone burden for non-staghorn calculi is also associated with lower stone free rates.[34] Some smaller cystine stones can be effectively treated with SWL, but large cystine stones are frequently inadequately treated with SWL. For instance, Kachel et al reported successful SWL for cystine stones < 1.0 cm, 1.0-1.5 cm, and >1.5 cm in 66%, 50%, and 0% of the time.[45] Despite the noninvasive nature of SWL, the procedure is also associated with potential complications. All patients should receive parenteral antibiotics to decrease the chance of sepsis. Patients with severe flank pain postoperatively should have a CT scan to exclude perirenal or retroperitoneal bleeding and ureteral obstruction. As stone burden increases, the incidence of steinstrasse and ureteral obstruction are also increased.[4] Stone fragments can also act as a nidus of stone regrowth. For example, Beck et al noted patients with more than 5 mm residual stone following SWL monotherapy had a progression rate of 78% at 3 months follow-up.[46] In addition, Streem et al followed 160 patients with clinically insignificant residual stone fragments following SWL and noted at a mean of 23 months postoperatively, 43% had a symptomatic episode or required intervention at an average of 26 months postoperatively.[47]

Ureteroscopic nephrolithotomy. Improvements in ureteroscopes have permitted easy access to the proximal ureter and renal pelvis. In addition, new technologies such as holmium:yttrium-aluminum-garnet (Ho:YAG) lithotripy have shown great efficiency in treatment of upper tract stones.[23] In favorable circumstances, stones in the proximal ureter and kidney can be fragmented and removed ureteroscopically. Mugiya et al treated 20 upper tract stones with the 200mm holmium laser fiber and reported a stone-free rate of 100%.[48] In a similar investigation, Grass et al reported on a group of 45 patients with minor staghorn calculi and found a stone-free rate of 76% after a single treatment. Following a second procedure in 8 patients with residual fragments, the investigators reported a 91% stone-free rate.[49] The incidence of ureteroscopic complications is rare with the introduction of modern instruments. Nonetheless, the ureteroscopic treatment of upper tract stones is more challenging than cystoscopy and the potential complications are more significant. Most patients are left with an indwelling double-J stent following this procedure.

Open surgery. Nephrolithotomy is currently considered a treatment option only for large staghorn calculi that have failed attempts at removal with less invasive treatments or for large staghorn calculi that would otherwise require multiple noninvasive treatments. Open stone removal is also indicated in conjunction with other procedures such as dismembered pyeloplasty that improve urine drainage. Advantages of open stone surgery are that the patient can have a stone removed by a single procedure with a single hospitalization. Complication rates for open surgery are similar to PL. Money et al reported on 16 anatrophic nephrolithotomies performed between 1987 and 1997. An open approach was selected for all patients because of the complex nature of the stones. For this series, an 81% stone-free rate was obtained without major complications.[50]

Combination therapy. Use of staged endourologic techniques for stone treatment is referred to as combination therapy. Most combination treatments incorporate the strengths of PL and SWL to provide safe and effective treatment of staghorn stones. The most popular regimen, referred to by Streem et al as sandwich therapy,[51,52] combines an initial PL, followed by SWL, and then a second PL to remove residual debris. Some combination treatment regimens have not proven as effective. The combination of PL followed by SWL alone at our institution resulted in only a 23% stone-free rate.[53] These results underscore the importance of the second PL procedure. Combined therapy is best utilized for complex cases that preclude use of monotherapy alone. Using combined therapy, Schultz and colleagues reported a 77% stone-free rate,[54] Lam and associates noted a 78% stone-free-rate,[44] and Streem et al noted an improved stone-free rate from 52% to 70% over time for complex stones.[51] Recently, another combination treatment involving use of ureteroscopic lithotripsy in combination with SWL has shown promising results. Mugiya et al noted this combination resulted in a 61% stone-free rate for complete staghorn calculi and an 80% stone-free rate for partial staghorn calculi.[55]

Management of distal ureteral stones. Surgical options for distal ureteral stones include URS, extracorporeal SWL, or open surgery. The surgical technique for distal ureteral stones is influenced by many factors, although with distal ureteral stones patient preference may be a more important factor. The American Urological Association has also devised guidelines for management of distal ureteral stones.[24] According to the guidelines, patients should be informed and offered all available treatment options. As a guideline, patients with a stone $\leq$ 0.5 mm in diameter are candidates for conservative treatment with periodic evaluation. The timing of intervention in this instance is subjective; indeed, any form of patient intolerance would warrant active treatment. As a guideline, blind basketing procedures are not acceptable treatment of distal ureteral stones. The recommended first line treatment for stones in the distal ureter is URS or SWL. Open surgery is used as a salvage procedure or in unusual circumstances. Use of SWL versus URS as the most effective treatment of distal ureteral stones is currently debatable (Table 3).[56-61]

Ureteroscopy. Ureteroscopy is an effective treatment for distal ureteral stones. Improved ureteroscopes today permit easy access to the distal ureter frequently without ureteral dilation. Improved fragmentation devices, such as Ho:YAG laser, have also shown great treatment efficiency for larger distal stones. Smaller stones can frequently be removed primarily with a stone retrieval device. In recent reports, excellent treatment rates and few failures have been noted with URS. For example, Peschel et al reported on a group of 40 patients with distal calculi prospectively randomized to URS. All patients were treated with a 9.5 F or a 6.5 F semirigid ureteroscope.[56] A 100% success rate was reported.

Table 3 - Comparison of treatment options for distal ureteral stones.

Treatment	Advantages	Disadvantages
Lithotripsy	least invasive few associated complications outpatient procedure conscious sedation possible	lower stone-free rates more retreatment not always available
Ureteroscopy	essentially 100% stone-free rate less complications today widely available to all urologists low retreatment rate less expensive	often full anesthsia more invasive possible stent needed

The mean time to a stone-free state was 0.2 days for stones < 5 mm and 3.7 days for stones > 5 mm. Ureteroscopy, in their series, was also associated with shorter operative times and less fluoroscopy time. With the introduction of modern instruments, the incidence of ureteroscopic complications is rare. Typically after ureteroscopy patients are left with an indwelling double-J stent, however this is not an absolute requirement.

Lithotripsy. Shock wave lithotripsy is also considered a first-line therapy for distal ureteral stones.[24] The technique is the least invasive available treatment, especially with the introduction of 2nd and 3rd generation lithotripsy devices. In previous investigations, overall stone-free rates of 42-96% were reported for distal ureteral stones.[56-61] The choice of lithotripsy device has a significant impact on treatment efficacy of distal ureteal stones. Similar to use of URS, some patients are better candidates than others are for this procedure. Most importantly patients must accept a higher possibility that retreatment will be needed. In addition, patients must expect a longer period of time to become stone-free. These issues aside, patients can be subjected to a totally noninvasive treatment often under conscious sedation without the need for a ureteral stent. Other factors influencing the success of SWL include stone burden, body habitus, intraoperative visualization of the stone during lithotripsy. Anderson et al compared URS to SWL administered with either the HM3 or the Lithostar lithotripsy machines. Stone-free rates were 96% for the HM3, 84% for the Lithostar, and 100% for ureteroscopy.[61] They noted URS was more time consuming, required routine stent placement, more often required general anesthesia, led to longer hospital stay, and doubled the convalescence. Based on this data, they recommended SWL as first line treatment and URS as a salvage procedure for SWL failures.

Open surgery. Nephrolithotomy is essentially considered a treatment option only for distal stones that have failed endourologic treatment.[24] Use of open surgery for distal ureteral stones is exceedingly rare in the standard patient. In the report by Kane et al, indications for 8 patients undergoing ureterolithotomy included failed URS (2 patients), failed URS and SWL (1 patient), impacted stones (2 patients), simultaneous anatrophic nephrolithotomy (2 patients), and simultaneous prostatectomy (1 patient).[62]

In conclusion, the diagnosis and management of renal and ureteral stones requires a systematic clinical approach. After making the diagnosis of a urinary stone, the urologist should discuss the advantages and disadvantages of all treatment options with the patient. For most stone patients, many equally effective treatment approaches can exist for the same problem. With technologic advances, stone treatments have improved and complications have decreased. While patient care has been significantly impacted by use of effective endourologic techniques, all patients should complete postoperative imaging to assure a stone-free state. In addition, recurrent stone formers should complete a medical stone clinic evaluation to identify treatable causes of their stones.

References

1. National Institutes of Health Consensus Development Conference on Prevention and Treatment of Kidney Stones. J Urol 1989; 141: 705-808.
2. Coe FJ, Favus MJ, Pak CYC, Park S, Preminger GM, editors. Kidney stones, medical and surgical management. Philadelphia: Lippincott-Raven; 1996.
3. Cohen TD, Preminger GM. Struvite calculi. Semin Nephrol 1996; 14: 425-434.
4. Segura JW. Staghorn calculi. Urol Clin North Am 1997; 24: 71-80.
5. Chow GK, Streem SB. Contemporary urologic intervention for cystinuric patients: immediate and long-term impact and implications. J Urol 1998; 160: 341-344.
6. Wasserstein AG. Nephrolithiasis: acute management and prevention. Dis Mon 1998; 44: 196-213.
7. Curhan GC, Willett WC, Rimm EB, Stampfer MJ. A prospective study of dietary calcium and other nutrients and the risk of symptomatic kidney stones. N Engl J Med 1993; 328: 833-838.
8. Pearle MS, Roehrborn CG, Pak CY. Meta-analysis of randomized trials for medical prevention of calcium oxalate nephrolithiasis. J Endourol 1999; 13: 679-685.
9. Laminski NA, Meyers AM, Kruger M, Sonneus MI, Margolius LP. Hyperoxaluria in patients with recurrent calcium oxalate calculi: dietary and other risk factors. Br J Urol 1991; 68: 454-458.
10. Borghi L, Meschi T, Amato F, Novarini A, Romanelli A, Cigala F. Hot occupation and nephrolithiasis. J Urol 1993; 150: 17-57.
11. Tsao JW, Kogan SC. Images in clinical medicine. Indinavir Crystalluria. N Eng J Med 1999; 340: 1329.
12. Eskelinen M, Ikonen J, Lipponen P. Usefulness of history-taking, physical examination and diagnostic scoring in acute renal colic. Eur Urol 1998; 34: 467-473.
13. Niall O, Russell J, MacGregor R, Duncan H, Mullins J. A comparison of noncontrast computerized tomography with excretory urography in the assessment of acute flank pain. J Urol 1999; 161: 534-537.
14. Vieweg J, Teh C, Freed K, Leder RA, Smith RHA, Nelson R et al. Unenhanced helical computerized tomography for the evaluation of patients with acute flank pain. J Urol 1998; 160: 679-684.
15. Miller OF, Rineer SK, Reichard SR, Buckley RG, Donovan MS, Graham IR et al. Prospective comparison of unenhanced spiral computed tomography and intravenous urogram in the evaluation of acute flank pain. Urology 1998; 52: 982-987.
16. Fielding JR, Steele G, Fox LA, Heller H, Loughlin KR. Spiral computerized tomography in the evaluation of acute flank pain: a replacement for excretory urography. J Urol 1997; 157: 2071-2073.
17. Sullivan K, Badley DH. Spiral computed tomography for staghorn calculi. Urology 1997; 50: 519-524.
18. Boridy IC, Kawashima A, Goldman SM, Sandler CM. Acute ureterolithiasis: nonenhanced helical CT findings of perinephric edema for prediction of degree of ureteral obstruction. Radiology 1999; 213: 663-667.

19. Mostafavi MR, Ernst RD, Saltsman B. Accurate determination of chemical composition of urinary calculi by spiral computerized tomography. J Urol 1998; 159: 673-675.
20. Nakada SY, Hoff DG, Attai S, Heisey D, Blankenbaker D, Pozniak M. Determination of stone composition by noncontrast spiral computed tomography in the clinical setting. Urology 2000; 55: 816-819.
21. Pearle MS, Pierce HL, Miller GH, Summa JA, Mutz JM, Petty BA et al. Optimal method of urgent decompression of the collecting system for obstruction and infection due to ureteral calculi. J Urol 1998; 160: 1260-1264.
22. Ueno A, Kawamura T, Ogawa A et al. Relation of spontaneous passage of calculi to size. Urology 1977; 10: 544-546.
23. Hubner W, Irby P, Stoller M. Natural history and current concepts for the treatment of small ureteral calculi. Eur Urol 1993; 24: 172-176.
24. Segura JW, Preminger GM, Assimos DG, Dretler SP, Kahn RI, Lingeman JE. Ureteral stones clinical guidelines panel summary report on the management of ureteral calculi. J Urol 1997; 158: 1915-1921.
25. Segura JW, Preminger GM, Assimos DG, Dretler SP, Kahn RI, Lingeman JE et al. Nephrolithiasis clinical guidelines panel summary report on the management of staghorn calculi. J Urol 1994; 151: 1648-1651.
26. Chandhoke PS. Cost-effectiveness of different treatment options for staghorn calculi. J Urol 1996; 156: 1567-1571.
27. Pearle MS, Watamull LM, Mullican MA. Sensitivity of noncontrast helical computerized tomography and plain film radiography compared to flexible nephroscopy for detecting residual fragments after percutaneous nephrostolithotomy. J Urol 1999; 162: 23-26.
28. Segura JW, Patterson DE, LeRoy AJ, Williams HJ Jr, Barrett DM, Benson RJ et al. Percutaneous removal of kidney stones: Review of 1000 cases. J Urol 1985; 134: 1077-1081.
29. Patterson DE, Segura JW, LeRoy AJ. Long-term follow-up of patients treated by percutaneous ultrasonic lithotripsy for struvite staghorn calculi. J Endourol 1987; 1: 177-180.
30. Lee WJ, Smith AD, Cubelli V, Vernance FM. Percutaneous nephrolithotomy: analysis of 500 consecutive cases. Urol Radiol 1986; 8: 61-66.
31. Chibber PJ. Percutaneous nephrolithotomy for large and staghorn calculi. J Endourol 1993; 7: 293-295.
32. Pearle MS, Nakada SY, Womack JS, Kryger JV. Outcomes of contemporary percutaneous nephrostolithotomy in morbidly obese patients. J Urol 1998; 160: 669-673.
33. Lingeman JE, Coury TA, Newman DM, Kahnoski RJ, Mertz JH, Mosbaugh PG et al. Comparison of results and morbidity of percutaneous nephrostolithotomy and extracorporeal shock wave lithotripsy. J Urol 1987; 138: 485-490.
34. Lingeman JE, Group LPS. Prospective randomized trial of extracorporeal shock wave lithotripsy and percutaneous nephrostolithotomy for lower pole nephrolithiasis [abstract]. J Endourol 1995; 9 Suppl 1: S64.
35. Netto NR Jr, De Almeida Claro JF, Ferreira U, Lemos GC. Lumbar ureteric stones: which is the best treatment? Urology 1991; 38: 443-446.
36. Kahn R. Endourological treatment of ureteral calculi. J Urol 1986; 135: 239-243.
37. Liong M, Clayman R, Gittes R, Lingeman JE, Huffman JL, Lyon ES. Treatment options for proximal ureteral urolithiasis: review and recommendations. J Urol 1989; 141: 504-509.
38. Meretyk S, Gofrit ON, Gafni O, Pode D, Shapiro A, Verstandig A et al. Complete staghorn calculi: random prospective comparison between extracorporeal shock wave lithotripsy monotherapy and combined with percutaneous nephrostolithotomy. J Urol 1997; 157: 780-786.
39. Delaney CP, Creagh TA, Smith JM, Fitzpatrick JM. Do not treat staghorn calculi by extracorporeal shockwave lithotripsy alone! Eur Urol 1993; 24: 355-357.
40. Vandeursen H, Baert L. Extracorporeal shock wave lithotripsy monotherapy for staghorn stones with the second generation lithotriptors. J Urol 1990; 143: 252-256.
41. Danuser H, Ackermann DK, Marth DC, Studer UE, Zingg EJ. Extracorporeal shock wave lithotripsy in situ or after push-up for upper ureteral calculi: a prospective randomized trial. J Urol 1993; 150: 824-826.
42. Elbahnasy AM, Clayman RV, Shalhav AL, Hoenig DM, Chandhoke P, Lingeman JE et al. Lower-pole caliceal stone clearance after shockwave lithotripsy, percutaneous nephrolithotomy, and flexible ureteroscopy: impact of radiographic spatial anatomy. J Endourol 1998; 12: 113-119.
43. Havel D, Saussine C, Fath C, Lang H, Faure F, Jacqmin D. Single stones of the lower pole of the kidney. Comparative results of extracorporeal shock wave lithotripsy and percutaneous nephrolithotomy. Eur Urol 1998; 33: 396-400.
44. Lam HS, Lingeman JE, Barron M, Chua GT. Staghorn calculi: analysis of treatment results between initial percutaneous nephrolithotomy and extracorporeal shock wave lithotripsy monotherapy with reference to surface area. J Urol 1992; 147: 1219-1225.
45. Kachel TA, Vijan SR, Dretler SP. Endourological experience with cystine calculi and a treatment algorithm. J Urol 1991; 145: 25.
46. Beck EM, Riehle RA. The fate of residual fragments after extracorporeal shock wave lithotripsy for infection stones. J Urol 1991; 145: 6-10.
47. Streem SB, Yost A, Masha E. Clinical implications of clinically insignificant stone fragments after extracorporeal shock wave lithotripsy. J Urol 1996; 155: 1186-1190.
48. Mugiya S, Ohhira T, Un-No T, Takayama T, Suzuki K, Fujita K. Endoscopic management of upper urinary tract disease using a 200-mm holmium laser fiber: initial experience in Japan. Urology 1999; 53: 60-64.
49. Grasso M, Conlin M, Bagley D. Retrograde ureteropyeloscopic treatment of 2 cm or greater upper urinary tract and minor Staghorn calculi. J Urol 1998; 160: 346-351.
50. Morey AF, Nitahara KS, McAninch JW. Modified anatrophic nephrolithotomy for management of staghorn calculi: is renal function preserved? J Urol 1999; 162: 670-673.
51. Streem SB, Yost A, Dolmatch B. Combination "sandwich" therapy for extensive renal calculi in 100 consecutive patients: immediate, long-term and stratified results from a 10-year experience. J Urol 1997; 158: 342-345.
52. Streem SB, Lammert G. Long-term efficacy of combination therapy for struvite staghorn calculi. J Urol 1992; 147: 563-566.
53. Segura JW, Patterson DE, LeRoy AJ. Combined percutaneous ultrasonic lithotripsy and extracorporeal shock wave lithotripsy for struvite staghorn calculi. World J Urol 1987; 5: 245.
54. Schulze H, Hertle L, Kutta A, Graff J, Senge T. Critical evaluation of treatment of staghorn calculi by percutaneous nephrolithotomy and extracorporeal shock wave lithotripsy. J Urol 1989; 141: 882-895.
55. Mugiya S, Suzuki K, Ushiyama T, Fujita K. Combined treatment of staghorn calculi by fiberoptic transurethral nephrolithotripsy and extracorporeal shock wave lithotripsy. Int J Urol 1998; 5: 129-133.
56. Peschel R, Janetschek G, Bartsch G. Extracorporeal shock wave lithotripsy versus ureteroscopy for distal ureteral calculi: a prospective randomized study. J Urol 1999; 162: 1909-1912.

57. Netto NR Jr, De Almeida Claro J, Esteves SC, Andrade EFM. Uteroscopic stone removal in the distal ureter. Why change? J Urol 1997; 157: 2081-2083.
58. Bierkens AF, Hendrikx AJM, De La Rosette JJMCH, Stultiens GNM, Beerlage HP, Arends AJ et al. Treatment of mid and lower ureteric calculi: extracorporeal shock-wave lithotripsy vs laser ureteroscopy. A comparison of costs, morbidity, and effectiveness. Br J Urol 1998; 81: 31-35.
59. Kupeli B, Biri H, Isen K, Onaran M, Alkibay T, Karaoglan U et al. Treatment of ureteral stones: comparison of extracorporeal shock wave lithotripsy and endourologic alternatives. Eur Urol 1998; 34: 474-479.
60. Deliveliotis C, Stavropoulos NI, Koutsokalis G, Kostakopoulos A, Dimopoulos C. Distal ureteral calculi: ureteroscopy vs. ESWL. A prospective analysis. Int Urol Nephrol 1996; 28: 627-631.
61. Anderson KR, Keetch DW, Albala DM, Chandhoke PS, McClennan BL, Clayman RV. Optimal therapy for the distal ureteral stone: extracorporeal shock wave lithotropsy versus ureteroscopy. J Urol 1994; 152: 62-65.
62. Kane CJ, Bolton DM, Stoller ML. Current indications for open stone surgery in an endourology center. Urology 1995; 45: 218-221.