REVIEW

Minimally Invasive Surgical and Medical Management of Urinary Calculi

Palaniappan Sundaram, *MBBS, MRCS,* Yeh Hong Tan, *MBBS, FRCS*
Department of Urology, Singapore General Hospital

ABSTRACT

Management of urinary calculi has changed from open pyelolithotomy and ureterolithotomy to predominantly non-invasive procedures such as extracorporeal shockwave lithotripsy (ESWL) as well as endourological such as ureterorenoscopy (URS) and percutaneous nephrolithotripsy (PCNL). Technology has advanced rapidly allowing stone disease to be treated with minimally invasive techniques that have lower morbidity than the open operations of the past. Newer semi-rigid ureteroscopes of size 7 to 9 F allow visualisation of the ureter without traumatic dilatation. There is the flexible ureteroscope developed with smaller fibre optics, the addition of the working channel that allows the use of laser fibres for stone fragmentation and a greater deflection of the tip that enables all parts of the pelvicalyceal system to be inspected for stones. New generation lithotripters for ESWL deliver shockwave to a smaller focal zone so as to minimise damage to surrounding soft tissue but as a result, there are higher failure rates. PCNL, though more invasive than ESWL and URS, is the procedure of choice for large renal stones. It is highly efficient in such situations as newer equipment to disintegrate stone and newer techniques for percutaneous access has been developed. In addition to all these minimally invasive surgical techniques, there is medical therapy available to allow the expulsion of distal ureteric stones as well as alkalinising agents to dissolve uric acid stones. Metabolic evaluation is necessary for patients with recurrent stones. Dietary adjustments may help prevent recurrent stone formation in selected patients depending on the results. With all these techniques currently available, management of urinary calculi has to be tailored according to the size, location of stone as well as patient preference.

Keywords: Extracorporeal shockwave lithotripsy (ESWL), Kidney stones, Ureteric stones, Ureterorenoscopy (URS), Percutaneous nephrolithotripsy (PCNL)

INTRODUCTION

Urinary calculi affects about 5–15% of the population in industrialised countries[1]. It is three times more likely to affect men than women. They almost always originate in the kidney and migrate to the ureter where they may grow. They often present with pain, haematuria or infection. Imaging of choice is non-contrast computed tomography (CT) of the kidney, ureter and bladder which is rapid and has a sensitivity of 99%. CT KUB has superseded intravenous urography (IVU) as it does not carry any risk associated with intravenous contrast and it can be performed on patients with abnormal renal function.

MINIMALLY INVASIVE SURGICAL MANAGEMENT

When a stone is confirmed on imaging, the most important aspect of management is the identification of those who develop sepsis in conjunction with an obstructing stone as well as those who have bilateral obstruction or unilateral obstruction in patients with a solitary kidney which will result in anuria and acute renal failure. These patients will require immediate decompression of the obstructed system with either a percutaneous nephrostomy or retrograde ureteral stent insertion. The remaining patients can be managed with adequate analgesia and close follow-up until spontaneous passage or intervention instituted.

Ureteral stones of up to 5mm should be given an opportunity to pass spontaneously; 71–98% of such stones generally pass out within a few weeks[2]. Miller and Kane reported that stones of size <2mm, 2–4mm and 4–6mm passed out by 31, 40 and 39 days, respectively[3]. Larger stones are unlikely to have spontaneous passage. Medical expulsion therapy (MET) can be attempted to increase stone expulsion rate. As the ureters are lined by smooth muscle which has alpha adrenoceptors, alpha

blockers such as tamsulosin may reduce the ureteric spasm and allow normal peristalsis to facilitate stone passage out of the ureter[4,5]. Dissolution therapy is reserved for selected patients with uric acid stones. In such patients, potassium citrate would alkalinise the urine enabling the stone to dissolve over time.

Ureteric calculi may occur in either proximal, mid or distal segments. The proximal ureter is from the pelviureteric junction (PUJ) to the sacroiliac joint. The distal ureter is from the sacroiliac joint to the vesicoureteric junction while the mid ureter is the portion of ureter overlying the sacroiliac joint. Renal calculi can either be a pelviureteric junction stone, calyceal stone or large staghorn stone. In general renal stones are largely asymptomatic but 50% of small renal calculi become symptomatic after five years[6].

In patients with failed conservative treatment, either extracorporeal shockwave lithotripsy (ESWL), ureterorenoscopy (URS) or percutaneous nephrolithotripsy (PCNL) is available. ESWL is performed as an outpatient procedure and is well-tolerated with opiate analgesia. Being minimally invasive and having low complication rates, it revolutionised stone treatment in the 1980s when it was introduced. It has good stone-free rates; 82% in the upper ureter and 73% in the mid-ureter and 74% in the distal ureters[7]. These stones should be radio opaque so that they can be localised for the ESWL. It attempts to break up the stone with externally applied acoustic energy such as electromagnetic, electrohydraulic and piezoelectric. Once fragmented, these can easily pass through the ureter. The absolute contraindications are uncorrected coagulopathy, urosepsis and pregnancy. The potential complications include perinephric haematoma, infection and steinstrasse. No improved fragmentation is seen with stenting prior to ESWL[2]. Hence stenting is not indicated unless it is a solitary kidney. Large stone size of more than 20mm is likely to have repeat treatment and more complications when compared with URS[8]. Pace et al showed that repeat ESWL after an initial failed treatment has low success rates. Success rates after one ESWL session was 68% while after the second session was 76%, and after the third session was 77%[9]. Hence ESWL takes longer to achieve stone-free status and may even require secondary intervention. Reduced effectiveness of ESWL may be related to the hardness of the stone. Morbid obesity makes ESWL less effective too.

Ureterorenoscopic stone removal (URS) is a viable alternative for the removal of urinary stones. Miniaturisation in ureteroscope design has allowed for small calibre semi-rigid and flexible ureteroscope to be developed with good optical quality. In addition, the introduction of the holmium/YAG laser, which has a low penetration of only 0.5mm, reduced the risk of injury to the ureteric mucosa. Its precise vaporisation and fragmentation has enhanced stone clearance. These technical advances allowed the evolution of URS into a safer technique for access to all locations of the ureter[10]. Flexible ureteroscope allows examination of the pelvicalyceal system and clearance of migrated stone fragments. Baskets can be deployed through the ureteroscope to retrieve these fragments. Complications associated with the procedure such as ureteral perforation is less than 5% while ureteric stricture is less than 2%[11]. After most uncomplicated URS, the ureter does not require stenting[12] but if ureteral injury, oedema and stricture were encountered or if the patient had solitary kidney or large stone burden, stenting is indicated. Ureteral stenting is associated with haematuria, dysuria, frequency, nocturia and flank pain[13] and also has its own complications such as urinary tract infection, stent migration, breakage, encrustation and obstruction. URS can be performed safely in patients where anticoagulation cannot be stopped[14]. It can also be used effectively in morbidly obese patient where ESWL may not be possible[15]. Bilateral ureteral stones are also simultaneously treated with URS[16].

Percutaneous nephrolithotripsy (PCNL) is usually reserved for large renal stones >20mm and staghorn calculi as well as large impacted upper ureteric stones >15mm. Endoscopic access is obtained via needle puncture into an appropriate calyx depending on the location of the stone. After dilatation of the tract, access is maintained with a sheath through which stone fragmentation is performed. PCNL alone or combined with ESWL of staghorn calculi results in a higher stone-free rate of 76% when compared to ESWL which only results in 22%[17]. Staghorn stones are managed primarily by PCNL with one or more puncture depending on the configuration of the pelvicalyceal system. Flexible nephroscopy can be used to access the calyces which are not accessible by the rigid nephroscope.

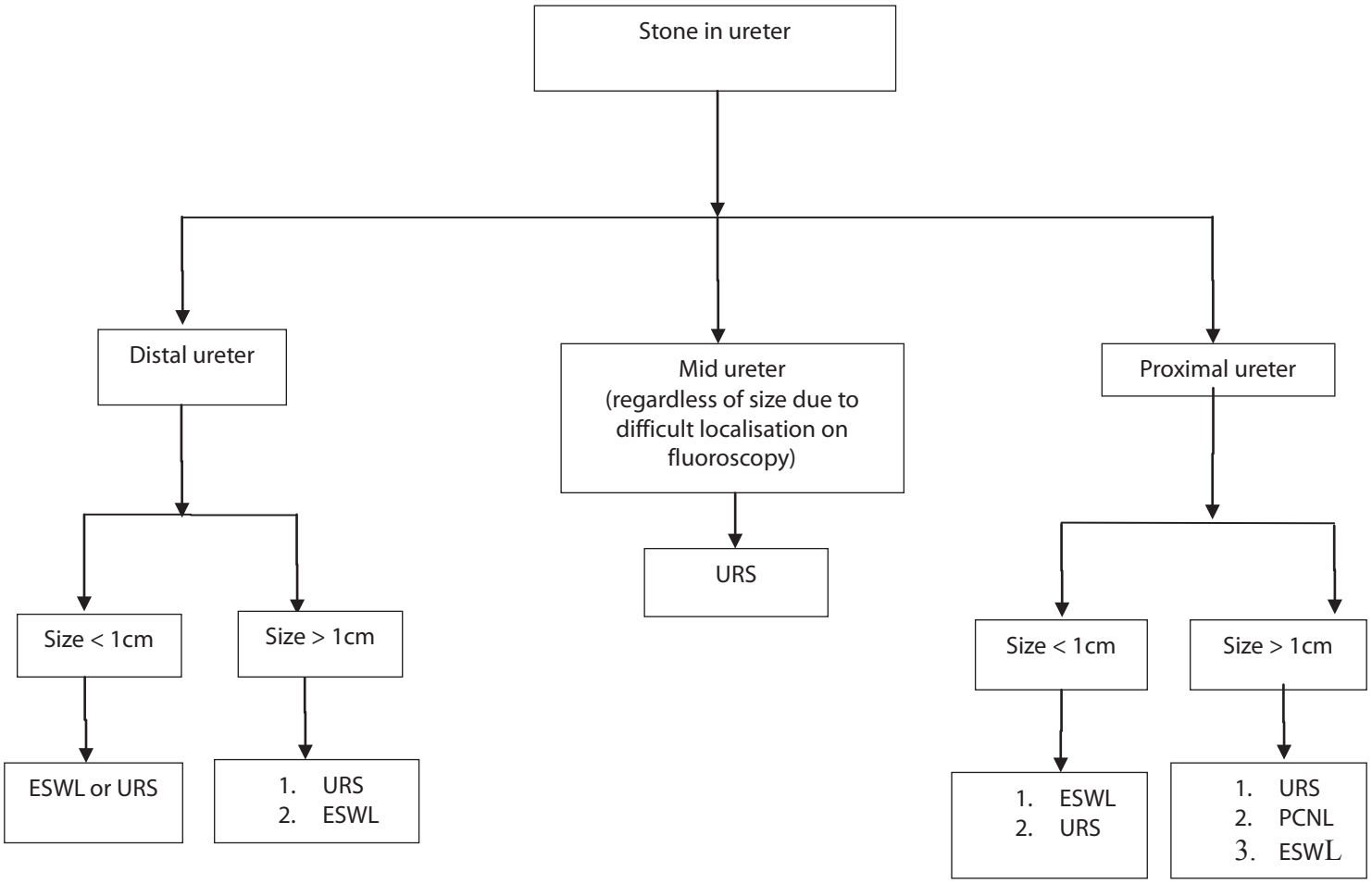

Fig. 1. Treatment algorithm for ureteric stone[19]
ESWL – Extracorporeal shockwave lithotripsy
URS – Ureterorenoscopy
PCNL – Percutaneous nephrolithotripsy

In addition, large stones of lower pole are best managed by PCNL[18]. Also PCNL is considered an alternative technique when ESWL has failed or when the retrograde access to the upper tract is not straightforward, such as in patients with urinary diversion or renal transplants. Complications of PCNL are infection, haemorrhage and damage to the lung, pleura or colon.

Proximal ureteric stone can be treated with either URS or ESWL. If the stone is less than 10mm, ESWL is preferred. However when the size is more than 10mm, URS achieves higher stone-free rates[19]. Similarly, stones in the distal ureter can be treated with ESWL but URS is able to clear them more effectively regardless of their size[7]. The recommended treatment algorithm is detailed in figure 1.

Stones in the renal pelvis or in the upper or middle calyx can either be treated with ESWL, flexible URS or PCNL. ESWL is the first line option if stones are smaller than 20mm but when larger, PCNL is indicated as ESWL will require multiple sessions and increases the risk of ureteral obstruction that may require additional treatment. When faced with multiple calyceal stones, flexible URS is the treatment of choice since ESWL will require multiple sessions while PCNL may require multiple punctures for access.

Lower pole stones may be treated with ESWL but stone clearance is limited due to the dependent nature of the calyx. Factors associated with poor clearance are infundibulopelvic angle less than 90 degree and a long and narrow infundibulum. Hence PCNL is recommended for stones more than 15mm while flexible URS can be employed

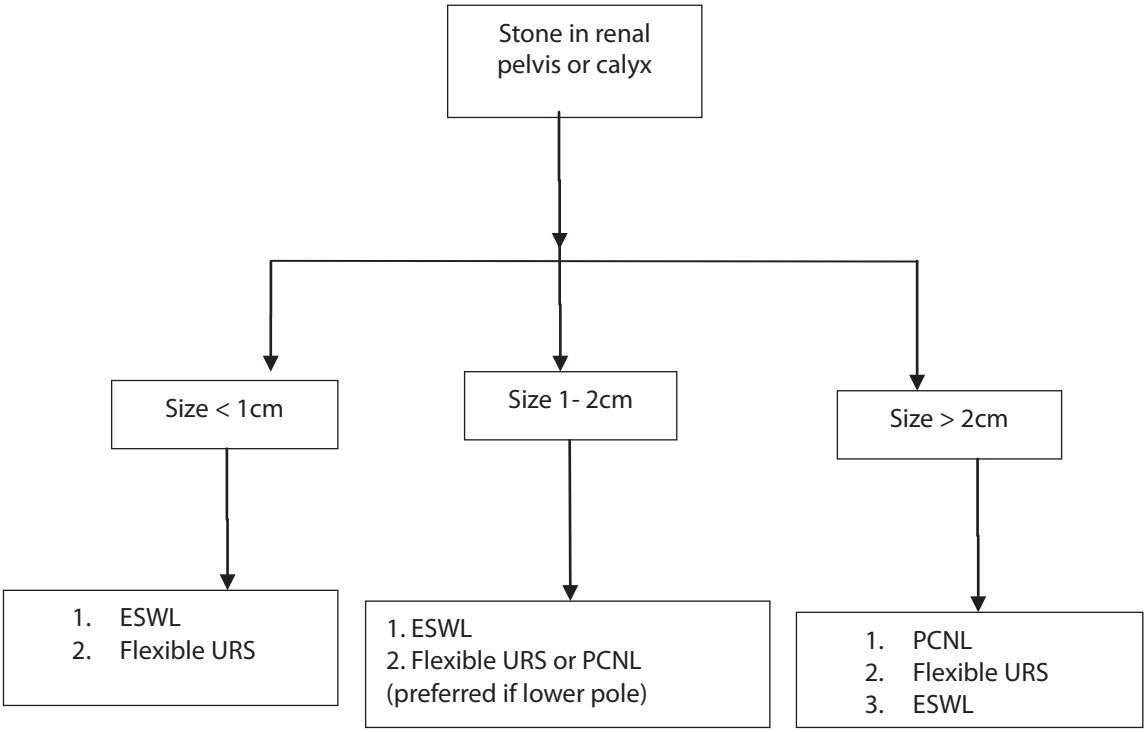

Fig. 2. Treatment algorithm for renal stone[19]
ESWL – Extracorporeal shockwave lithotripsy
URS – Ureterorenoscopy
PCNL – Percutaneous nephrolithotripsy

for stones smaller than 15mm since ESWL has poor results for such stones[19]. The recommended treatment algorithm is detailed in figure 2.

When dealing with multiple ureteric stones in which ESWL and URS have failed or when there is a large impacted stone, laparoscopic ureterolithotomy is an option[20]. This is not commonly performed as it is more invasive, has higher risk of complications and associated with longer recovery times.[7] However, laparoscopic ureterolithotomy remains an attractive minimally invasive alternative to open surgery for large upper ureteric stone in places where advanced endourological equipment are not available.

Stones that are small enough may spontaneously pass down from the upper tract into the bladder or the urethra where their passage may hindered. Bladder stones are also formed within the bladder as a result of incomplete emptying of the bladder due to a bladder outlet obstruction. These stones can be fragmented transurethrally using lithotrite or laser lithotripsy. If stones are larger, open vesicolithotomy may be the only option. Urethral stones are managed similarly to bladder stones after retrogradely advancing the stone back into the bladder.

MEDICAL MANAGEMENT OF URINARY STONE

Metabolic evaluation is essential in all patients. Stone analysis and serum calcium, phosphate and uric acid should be performed while 24-hour urine collection is reserved for patients who are recurrent stone formers to assess volume, sodium, potassium, magnesium, calcium, phosphate, uric acid, citrate, oxalate and creatinine. Raised calcium levels could be indicative of primary hyperparathyroidism while raised uric acid levels might suggest gouty diathesis with an increased incidence of uric acid stones. Urine analysis is very informative. The specific gravity of the urine reflects the general

hydration of the patient. Volume depletion would result in higher specific gravity. Urine pH >6.5 is likely to be secondary to urease producing bacteria such as *Proteus*, *Pseudomonas* or *Klebsiella* which are associated with struvite stone. Uric acid stones would cause the urine pH to be less than 5.5.

Dietary advice for all stone formers is recommended to reduce their risk of recurrence. Adequate fluid is advised to generate a urine output of at least two litres. A strict low salt diet would reduce hypercalciuria while a low animal protein diet would reduce uric acid production. In recurrent stone formers who have completed their metabolic evaluation, selective and non-selective medical prophylactic therapy (e.g. thiazides for hypercalciuria, potassium citrate for gouty diathesis) may be considered.

CONCLUSION

The evolution of stone management from an invasive surgical approach to one which is completely minimally invasive has been driven by advancements in technology. This evidence-based review serving as a current guideline for management though the judgement and experience of the urologist as well as patient preference is essential in the planning of treatment.

REFERENCES

1. Moe OW. Kidney stones: pathophysiology and medical management. Lancet 2006;367:333–44.
2. Segura JW, Preminger GM, Assimos DG, Dretler SP, Kahn RI, Lingeman JE, et al. Ureteral Stones Clinical Guidelines Panel Summary report on the management of ureteral calculi. J Urol 1997;158(5):1915–21.
3. Miller OF, Kane CJ. Time to stone passage for observed ureteral calculi: a guide for patient education. J Urol 1999;162:688–90.
4. Hollingsworth JM, Rogers MA, Kaufman SR, Bradford TJ, Saint S, Wei JT, et al: Medical therapy to facilitate urinary stone passage: a meta-analysis. Lancet 2006;368:1171.
5. Singh A, Alter HJ, Littlepage A. A systematic review of medical therapy to facilitate passage of ureteral calculi. Ann Emerg Med 2007;50:552–63.
6. Glowacki LS, Beecroft ML, Cook RJ, Pahl D, Churchill DN. The natural history of asymptomatic urolithiasis. J Urol 1992;147:319–21.
7. Preminger GM, Tiselius HG, Assimos DG, Alken P, Buck AC, Gallucci M, et al. Guideline for the management of ureteral calculi. Eur Urol 2007;52:1610–31.
8. Kijvikai K, Haleblian GE, Preminger GM, de la Rosette J. Shock wave lithotripsy or ureteroscopy for the management of proximal ureteral calculi: an old discussion revisited. J Urol 2007;178:1157–63.
9. Pace KT, Weir MJ, Tariq N, Honey RJ. Low success rate of repeat shock wave lithotripsy for ureteral stones after failed initial treatment. J Urol 2000;164:1905–7.
10. Yaycioglu O, Guvel S, Kilinc F, Egilmez T, Ozakardes H. Results with 7.5F versus 10F rigid ureteroscopes in treatment of ureteral calculi. Urology 2004;64:643.
11. Johnson DB, Pearle MS. Complications of ureteroscopy. Urol Clin North Am 2004:31:157.
12. Byrne RR, Auge BK, Kourambas J, Munver R, Delvecchio F and Preminger GM. Routine ureteral stenting is not necessary after ureteroscopy and ureteropyeloscopy: a randomized trial. J Endourol 2002;16:9.
13. Borboroglu PG, Amling CL, Schenkman NS, Monga M, Ward JF, Piper NY, et al. Ureteral stenting after ureteroscopy for distal ureteral calculi: a multi-institutional prospective randomized controlled study assessing pain, outcomes and complications. J Urol 2001;166:1651.
14. Watterson JD, Girvan AR, Cook AJ, Beilo DT, Nott L, Auge BK, et al. Safety and efficacy of holmium: YAG laser lithotripsy in patients with bleeding diatheses. J Urol 2002;168:442.
15. Dash A, Schuster TG, Hollenbeck BK, Faerver GJ, Wolf JS Jr. Ureteroscopic treatment of renal calculi in morbidly obese patients: a stone-matched comparison. Urology 2002;60:393.
16. Hollenbeck BK, Schuster TG, Faerber GJ, Wolf JS Jr. Safety and efficacy of same-session bilateral ureteroscopy. J Endourol 2003;17:881.
17. 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 157:780–6.
18. Albala DM, Assimos DG, Clayman RV, Denstedt JD, Grasso M, Gutierrez-Aceves J, et al. Lower pole I: a prospective randomized trial of extracorporeal shock wave lithotripsy and percutaneous nephrolithotomy for lower pole nephrolithiasis–initial results. J Urol 2001;166:2072–80.
19. Tiselius HG, Alken P, Buck C, Gallucci M, Knoll T, Sarica K, et al. Guidelines on urolithiasis. Arnhem, The Netherlands: European Association of Urology (EAU); 2008 Mar. p 128.
20. Hruza M, Schulze M, Teber D, Gozen AS, Rassweiler JJ. Laparoscopic techniques for removal of renal and ureteral calculi. J Endourol 2009;23:1713–8.