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Treatment of Lower Calyceal Kidney Stones; Flexible Ureteroscopy vs ESWL

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Abstract: Treatment of lower calyceal kidney stones; Flexible ureteroscopy vs ESWL

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1. The volume of the Lower Calyceal Kidney Stones problem:

Kidney stones (calculi) are mineral concretions in the renal calyces and pelvis that are found free or attached to the renal papillae. By contrast, diffuse renal parenchymal calcification is called nephrocalcinosis.[1]

Stones that develop in the urinary tract (known as nephrolithiasis or urolithiasis) form when the urine becomes excessively supersaturated with respect to a mineral, leading to crystal formation, growth, aggregation and retention within the kidneys. Globally, approximately 80% of kidney stones are composed of calcium oxalate (CaOx) mixed with calcium phosphate (CaP). Stones composed of uric acid, struvite and cystine are also common and account for approximately 9%, 10% and 1% of stones, respectively. Urine can also become supersaturated with certain relatively insoluble drugs or their metabolites, leading to crystallization in the renal collecting ducts (iatrogenic stones). [2]

Stone formation is a common disease, with an estimated 5year recurrence rate of up to 50%.[3] The prevalence of stones has been consistently increasing over the past 50 years and further increases are expected owing to changing lifestyle, dietary habits and global warming.[4] Obesity, diabetes, hypertension and metabolic syndrome are considered risk factors for stone formation; conversely, stone formers are at risk of hypertension, chronic kidney disease (CKD) and end-stage renal disease (ESRD).[2] The costs associated with stone disease have also risen, increasing from an estimated US\$2 billion in 2000 to over US\$10 billion in 2006 in the United States alone.[5]

2. The Current Management Modalities

Major advances have been made in the medical and surgical management of patients with kidney stones. Stones can be fragmented using shockwave lithotripsy (SWL) to enable them to pass in the urine, or surgically removed using percutaneous nephrolithotomy (PCNL) or retrograde intrarenal surgery (RIRS). PCNL involves direct endoscopic access into the kidney through an incision in the flank, whereas RIRS is performed using a flexible fibre-optic ureteroscope to access the upper urinary tract through natural passageways. Medical therapies are being used to ease stone passage, promote expulsion and reduce stone recurrence. Important advances have also been made in our understanding of stone pathogenesis. This Primer focuses on

the medical and surgical management currently practiced, as well as the contemporary understanding of stone pathogenesis.[2]

Patients with urinary stones generally present with the typical reno-ureteral colic and less frequently with loin pain; associated manifestations could be gross haematuria, vomiting and sometimes fever. However, patients can also be asymptomatic. A diagnosis of nephrolithiasis is only confirmed when a stone has been passed, has been extracted or destroyed, or has been identified in the urinary tract by imaging studies or surgery. Otherwise, other possible causes of the above manifestations should be investigated.[2]

A detailed medical history and physical examination is part of the evaluation of patients with a suspected stone. Clinical diagnosis generally needs to be supported by appropriate imaging. Renal and urinary tract ultrasonography can identify stones that are situated in the calices, the pelvis and the pyeloureteric and vesicoureteric junctions; it may also identify indirect signs of a stone such as pyeloureteric dilation and a perirenal film of extravasated urine. Indeed, ultrasonography has been shown to identify renal stones with a sensitivity of 70% and a specificity of 94%.[6] For ureteral stones, the sensitivity and specificity of ultrasonography is lower at 57.3% and 97.5%, respectively.[7] Plain abdominal X-ray imaging is generally not used anymore in the evaluation of a flank pain given its modest diagnostic performance (sensitivity and specificity of 44-77% and 80-87%, respectively), however, plain abdominal X-ray imaging might still have a role in distinguishing between radiopaque and radiolucent stones and in follow-up care.[8,9]

Intravenous urography, which was the historical goldstandard imaging technique for urolithiasis, has been replaced by non-contrast-enhanced CT (NCCT) owing to its higher sensitivity and specificity for identifying ureteral stones regardless of location, size and composition; its lack of contrast agents; and because it can recognize extraurinary causes of renal colic in 30% of patients. Moreover, NCCT can determine the stone density and inner structure, as well as the skin-to-stone distance, which are useful ahead of extracorporeal SWL.[10]

Surgical management

Over the past 30 years, the management of paediatric and adult patients with symptomatic kidney stones has evolved from open surgical lithotomy to minimally invasive endourological approaches. The three most common treatment modalities for renal stones include extracorporeal SWL (40–50% worldwide use), rigid or flexible retrograde ureteroscopic stone fragmentation and retrieval (30–40%) and PCNL (5–10%). Each of these therapies has its own particular adverse-effect profile and expected success rate depending on the experience of the treating physician, stone factors (size, location and composition) and patient characteristics (body habitus, medical co-morbidities and anatomy). With appropriate counselling and proper procedure selection, patients should expect high stone clearance rates, low associated morbidity and quick recovery times.[2]

Shockwave lithotripsy

SWL involves the non-invasive delivery of high-energy acoustic waves that fragment a kidney stone. The shockwave, created by electrohydraulic, electromagnetic or other types of energy sources, travels through the patient and is focused on the stone using an acoustic lens. When these shockwaves approach and pass through the calculus, energy is released resulting in internal structure disruption and stone fragmentation. Fluoroscopic or ultrasonographic guidance is routinely used during SWL to aid in calculus targeting and for precise acoustic-wave focusing. Deep sedation or general anaesthesia is commonly used for intraoperative analgesia, as well as to control respiratory renal movement. Although recent Canadian and US medical claims data have demonstrated a marked decrease in use over the past decade, SWL remains the most commonly performed endourological kidney stone procedure worldwide.[11]

3. Flexible ureteroscope pros and cons

Ureteroscopy consists of retrograde passage of an endoscope from the urethra proximally towards the affected ureter and kidney, enabling access to the stone as well as delivery of other instruments, such as guidewires, balloon dilators, laser fibres and baskets. Although fairly non-invasive, ureteroscopy requires spinal or general anaesthesia to minimize pain and the visceral response to ureteral and renal dilation. Rigid ureteroscopes are reserved for distal ureteral stones, whereas flexible ureteroscopes, with their deflection ability, are used to reach the extremes of the renal collecting system and negotiate access to anatomically difficult renal calyceal variants. Some urologists place ureteral access sheaths (long reinforced hollow tubes) from the urethra to the renal pelvis to enable repetitive passage of the ureteroscope while minimizing urothelial trauma. These sheaths also enable the continuous flow of irrigation fluid, improving stone visualization and facilitating a low-pressure system. Although flexible electrohydraulic lithotripters are available, the holmium yttrium-aluminium-garnet (Ho:YAG) laser remains the preferred method of lithotripsy in most centres in developed countries owing to its rapid absorption in water and minimal tissue penetration.[12]

A recent meta-analysis of seven large randomized controlled trials totalling >1,200 patients demonstrated that ureteroscopic retrieval achieved a higher ureteral and kidney stone-free rate and a lower need for retreatment than did SWL. As such, for ureteral stones <10 mm in size, SWL and ureteroscopy are considered first-line therapy. For ureteral stones >10 mm in size, ureteroscopic fragmentation results

in higher stone-free rates and fewer procedures.[13] For renal stones in non-dependent locations such as the lower pole, ureteroscopy stone-free rates are comparable to those of SWL, if not slightly better. Like SWL, ureteroscopic management of lower-pole stones is frequently more challenging than for stones located elsewhere in the kidney. Not only can acute infundibular angles make deflection and manoeuvring of the scope difficult but also the passage of the accessory instruments through the ureteroscope working channel reduces the ability of the surgeon to actively deflect the ureteroscope, creating a scenario in which a lower-pole stone can be visualized but not manipulated.[12] With the advent of smaller flexible endoscopes and tipless stone baskets, many endourologists relocate lower-pole stones into more-favourable upper-pole location before а fragmentation.[14]

Compared with SWL, ureteroscopy is associated with higher procedure-related complication rates and longer hospital stays. Many of the symptoms that raise complication rates are secondary to the ureteral stent that is left in place following the procedure.[13] These small, hollow polyurethane tubes are designed with proximal and distal coils to maintain their position within the kidney and the bladder. Unfortunately, the distal bladder coil can be felt by the majority of patients, causing haematuria and irritative voiding symptoms that range from mild to intolerable. Ureteroscopy is favoured over SWL in the setting of multiple or radiolucent stones (stones that are not visible on plain film), hydronephrosis, obesity or high-density stones (holmium lasers are able to fragment all stone types). Ureteroscopy for renal stones during pregnancy or in patients with bleeding diathesis is unusual but would be considered the safest approach, if necessary.[2]

4. ESWL pros and cons

The success of SWL is typically determined 1-3 months after the procedure by plain abdominal X-ray with or without renal ultrasonography. As small residual fragments of <4 mm in size within the kidney are considered to be passable, patients with these clinically insignificant stones are often referred to as stone free by most classification systems.[2] This misnomer becomes confusing when comparing stone-free rates among studies using plain abdominal X-ray versus CT imaging because CT is more sensitive than X-ray or renal ultrasonography for assessing residual kidney stones. Despite these discrepancies, stonefree rates for SWL are considered equivalent to those of ureteroscopic retrieval (50-80% success) for small radiopaque stones (<2 cm in size) located in non-dependent portions of the kidney (upper pole, middle pole or renal pelvis). Stones located in the lower pole of the kidney remain the most daunting clinical challenge for endourologists performing SWL. Multiple explanations have been offered for the poor stone-free rates for lower-pole stones, including anatomical factors (long, narrow lowerpole infundibulum) and the dependent position of the calculi limiting the passage of fragments.[12] Owing to these factors and the poor stone passage rates for larger stones, most clinicians do not perform SWL for lower-pole stones that are >1 cm in size.[14]

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In addition to lower-pole limitations, SWL might require repeated treatments to match the efficacies of PCNL and ureteroscopic retrieval. This retreatment risk is associated with obesity (a body mass index of >30) and with extremely dense stones. Patients who are obese are believed to have lower SWL success rates because their kidneys — and, accordingly, stone depth — exceed the lithotripter focal length (shockwaves only penetrate 12–14 cm) and/or their body habitus prevents adequate stone visualization at the time of lithotripsy.[2]

Dense stones, such as cystine, brushite or COM, are more resistant to SWL fragmentation. As stone composition is usually unknown before surgery, CT stone attenuation values in Hounsfield units (HUs) are commonly used as preoperative surrogates for stone density. Although variable, most urologists use high attenuation values of >1,000 HU as a predictor of renal stone disintegration failure that should be considered before undertaking SWL.[15]

Overall, most of the SWL shortcomings are surmounted by the excellent quality-of-life (QOL) measures and low morbidity associated with the procedure. Patients who undergo SWL have repeatedly been shown to have faster return to work, shorter recovery times and higher satisfaction scores than those who undergo ureteroscopic retrieval, especially if SWL occurs without stenting.[16] SWL also has a low complication profile, including a 5% rate of steinstrasse (that is, stone fragment build-up within the ureter) and a 2% rate of urinary tract infection. Major complications such as sepsis or profound haemorrhage are rare but deserve mention. The development of sepsis following SWL is low in absolute terms (<1% of patients), but is considerably higher in the presence of staghorn or colonized stones (up to 10% of patients). To mitigate this risk, patients with urinary obstruction or positive urine cultures before SWL should be completely treated. The majority of patients who undergo SWL develop transient haematuria that resolves within days, and imaging studies in asymptomatic patients post-procedure have shown a haematoma rate of 25%. However, symptomatic fluid collections (perirenal, subcapsular or intrarenal haematomas) are rare (<1% of patients), and the rate of post-SWL blood transfusions are very low (<0.2% of patients).[17,18]

5. Implications for the future

To date, the efficacy and safety of URS compared with ESWL has been evaluated in a few RCTs and several cohort studies. Recently, five RCTs and two out of three metaanalyses confirmed the superiority of URS in patients with lower pole kidney stones.[2,4] For non-lower pole kidney stones, however, only limited evidence exists. Only two RCTs included non-lower pole stones. The first study failed to accrue a sufficient number of patients.[19] The second RCT included only 46 obese patients and showed a significantly higher stone-free rate in the URS group (90.4% versus 68%).[20] The low number of patients and/or patient selection limits the validity for both studies. Thus, the available RCTs are inconclusive regarding treatment of non-lower pole stones.[2] Additionally, several cohort studies proposed the superiority of URS; however, they showed some evident limitations due to the nature of their study design.[5] Most of these retrospective cohort studies were small (with a mean of 162 patients) and no statistical methods to control for confounders were applied. To the best of our knowledge, our study including over 1200 patients is the largest retrospective study comparing the success rates of ESWL and URS for untreated renal calculi. Moreover, it is the first non-randomized cohort study that factors in known confounders such as age, sex, BMI, stone size and number of stones.[2]

In 2018, Christian D and colleagues reported that URS showed significantly better treatment success, which is reflected by higher stone-free and freedom from reintervention rate in comparison with ESWL. However, the higher stone-free rate after URS would be less game-changing if associated with distinctly higher rates of morbidity. As URS is considered as more invasive than ESWL, the assessment of treatment morbidity is crucial for further comparison of both interventions. In our large cohort study, we found a similarly low perioperative morbidity with very few relevant complications (Clavien Grade IIIa or IIIb complications) in both intervention groups. Our data confirmed that both interventions (ESWL and URS) are safe procedures, which is in line with previously published work.[2,4,5]

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