Retrograde Intrarenal Surgery (RIRS) - Ureterorenoscopic Lithotripsy for Renal Stones

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Introduction

Ever since the first ureteroscopy performed by Hugh Hampton Young at the beginning of last century,1 ureterorenoscopy has evolved over nearly a century from the era of happenstance to the Digital & Robotic era. This evolution culminates in the technique of retrograde intrarenal surgery (RIRS) utilising flexible ureterorenoscope and Holmium laser, which is a very effective treatment option in the Urologist’s armamentarium when first-line treatment options, viz, extracorporeal shockwave lithotripsy (ESWL) and percutaneous nephrolithotomy (PCNL) failed; it would also be used as first-line treatment in selected patients.

History

The first ureteroscopy began by happenstance.1 Hugh Hampton Young, the "Father of Modern Urology", introduced a Fr 12 Paediatric cystoscope into the massively dilated ureter of a child with posterior urethral valve in 1912. He was able to advance up to renal pelvis and became the first Urologist to view the intrarenal collecting system of a patient endoscopically. The enthusiasm for ureteroscopy cooled down until the first breakthrough in the late 1950’s with the development of the first fiberoptic endoscope. The first flexible ureterorenoscopy was performed by Marshall via an ureterotomy using a Fr 9 flexible endoscope for diagnostic purposes in 1964.2 But then it was not until 1977 that Goodman reported the first rigid ureteroscopy for therapeutic purposes1; whereas Fuchs & Fuchs (1990) reported the first large series (208 patients) of renal calculi treated by flexible ureteroscopy.3 The benchmark for contemporary RIRS using flexible ureterorenoscope and Holmium laser for treatment of renal stones was set by Grasso & Chalik in 19984.

Contemporary RIRS for Renal Stones

Instruments

Standard instruments for RIRS include:
- Flexible ureterorenoscope
- Holmium: yttrium-aluminium-garnet (YAG) laser
- Video camera
- Fluoroscopic support
- Accessory instruments
  - Guide-wires
  - Dilators
  - Access sheath
  - Basket
  - Ureteric catheters

Flexible Ureterorenoscope

Standard fiberoptic flexible ureterorenoscopes have a tip size in the range of 6.75 - 9Fr. They are actively deflectable (primary deflection) with 120 to 170 degrees of deflection in one direction and 170 to 270 degrees in the other. Secondary deflection will be passive or active (Fig. 1); active secondary deflection allows better manoeuvrability especially in the lower pole calyx. They have working channels of Fr 3.6 - 4 and standard instruments (e.g. baskets) are Fr 2.2 - 3 in size.

Holmium: YAG Laser

The Holmium:YAG laser is the lithotripter of choice for RIRS nowadays. It has a wavelength of 2100nm and tissue penetration of 0.4mm. The laser energy is delivered via quartz fibres to the stone surface, where it is absorbed and turned into heat energy that pulverises the stone into dust by a “photothermal” effect. Thus, stone fragment retrieval with basket / grasping forceps would not be necessary. Laser lithotripsy can be carried out safely in patients on anticoagulants.5 The size...
200micron laser fibre used in flexible ureterorenoscopy will minimise the hindrance to scope deflection (Fig 2). The usual laser setting on commencing the procedure would be 0.8J x 5 - 8Hz and then adjusted accordingly.

Video Camera and Fluoroscopy
Accurate and clear visualisation of the ureter and pelvi-calycal system using video camera is essential to the success of the procedure. Delineation of the pelvi-calycal anatomy using fluoroscopy and retrograde pyelogram helps the surgeon to orientate him/herself throughout the procedure.

Accessories

- **Guide-wires**
  The double flexible-tips guide-wire is essential for scope introduction in order to avoid damage to the flexible ureterorenoscope. Standard 0.038G PTFE-coated guide-wires would be used for the placement of ureteric catheters, introducing dilators / Access sheath and serve as safety guide-wire (Fig. 3a).

- **Dilators and Access Sheath**
  The use of Access sheath (Fig. 3b) is optional during RIRS, which would depend on the personal preference of the surgeon, stone load and pelvi-calycal anatomy. The size of commonly used Access sheathes include Fr 9/11 and Fr 12/14. Serial Teflon dilators up to size 16 would be used for ureteral calibration and dilatation before introducing the Access sheath over guide-wire under fluoroscopic guidance.

Advantages of using an Access sheath include:
1. Facilitate repeated introduction and withdrawal of the endoscope which would be required for patients with large stone burden;
2. Avoid build-up of pressure within the pelvi-calycal system especially when pressurised irrigating fluid is used to improve vision.

Disadvantages of using an Access sheath include:
1. Pre-stenting with double-J ureteric catheter for about 2 to 4 weeks for ureteric dilatation would be required to facilitate insertion of Access sheath especially for oriental patients with a less spacious ureter;
2. Traumaisation of the ureter may occur during ureteral dilatation and introduction of the Access sheath.

- **Baskets / Extractors**
  Development of the tipless Nitinol basket is vital for the success of RIRS of renal stones (Fig. 3c). Tipless design avoids traumatisation of the mucosa during intrarenal manipulations. Nitinol baskets also preserve tip deflection of the flexible ureterorenoscope. Relocation of lower pole stones into renal pelvis or upper pole calyx with basket will greatly enhance the efficiency of stone fragmentation. Extraction of stone fragments via the Access sheath would be considered in patients with large stone burden. Latest designs (e.g. NGate from Cooks Medical) allow a “frontal attack” to the stones instead of the usual sideway stone entrapment.

- **Ureteric Catheters**
  Standard Fr 6 / Fr 7 open-end ureteric catheters will be used for retrograde pyelogram at the beginning of the procedure and temporary drainage post-operatively. Fr 6 / Fr 7 double-J ureteric catheters will be used for pre-stenting or temporary stenting post-op.
Indications

Indications of RIRS for renal stones are listed as follows:
1. Failed Extracorporeal shockwave lithotripsy
2. Radiolucent stones
3. Concomitant ureteric and renal stones
4. Anatomical problems e.g. infundibular stenosis
5. Nephrocalcinosis
6. Bleeding disorders
7. Need for complete stone removal e.g. pilot

Pre-operative Assessment and Procedure

Imaging assessments on stone load, stone location and pelvi-calyceal anatomy are essential before the procedure. Intravenous urogram is the most commonly used imaging modality. Pre-operative retrograde pyelogram would be required for patients with impaired renal function. CT urogram is becoming more and more popular nowadays. An informed consent should be obtained including counselling on treatment options, procedure and potential complications, whereby possibilities of requiring post-op stenting, second-look procedure, auxiliary procedure and failed procedure are all thoroughly explained. Urine cultures are performed to ensure that patients have sterile urine before the procedure. Patients with asymptomatic persistent bacteriuria should be given an appropriate antibiotic for prophylaxis. Patients are put under general anaesthesia with prophylactic antibiotics administered on-induction. With the patient in Lloyd-Davis position, cystoscopy and retrograde pyelogram (RP) are performed to delineate upper tract anatomy and any stone migration before instrumentation is noted. Essential points of RIRS:

- Safety guide-wire inserted up to renal pelvis;
- Ureteric dilatation and use of Access sheath as preferred / indicated;
- Flexible ureterorenoscope "rail-roaded" up to renal pelvis over double-flexible tips guide-wire under fluoroscopic and endoscopic guidance;
- Systematic inspection of the pelvi-calyceal system to identify pathology endoscopically under saline irrigation (pressurised irrigant as required, preferably with Access sheath) and aided with fluoroscopy / RP as required;
- Commence lithotripsy with Holmium laser;
- Stone relocation / retrieval with basket as indicated;
- Assess stone clearance with endoscopy / fluoroscopy / RP;
- Placement of double-J ureteric catheter as indicated.

Post-operative ureteric stenting is optional and routine ureteric stenting after uncomplicated ureteroscopy is not necessary. Indications for post-operative ureteric stenting include ureteric injury, ureteric stricture, solitary kidney, renal insufficiency and a large residual stone burden.

Post-operative Management and Follow-up

RIRS for renal stones can be performed as Day-surgery in selected patients, viz, patients with stable / no comorbidity, smaller stone burden as well as uncomplicated procedure. Continuation of antibiotics is optional, but it would be preferable in patients with long procedure / persistent bacteriuria pre-op.

Patients will usually have their first follow-up visit scheduled about 2 weeks post-op. Treatment outcome will be assessed with a KUB radio-graph or additional imaging as indicated.

Outcome of RIRS for Renal Stones

Michael Grasso was credited for setting the benchmark of contemporary RIRS for renal stones. 228 patients were treated with RIRS in his series reported in 2000. Overall success rate (stone fragment <2mm in size) was 81% after primary RIRS and improved to 90% after secondary RIRS. Best results were achieved for upper & mid-pole stones with 90% success rate after primary treatment and up to 97% success after secondary RIRS. Grasso & Ficazzola have reported their results of RIRS in treating lower pole renal calculi. 101 RIRS were performed in 79 patients. Patients were analysed in 3 groups with stone sizes of 10mm or less (group 1), 20mm or less (group 2) and more than 20mm (group 3). The overall complete fragmentation rate (stone fragment <2mm in size) was 91%. Complete fragmentation rate was 94% and 95% for group 1 and 2 respectively after one session; it was 45% after one session and 82% after two sessions for group 3.

The excellent results of Grasso inspired the Lower Pole II study, which was a prospective randomised study involving 19 centres. Patients with lower pole renal stones of 1cm or less were randomised to receive ESWL or flexible ureterorenoscopy (URS). 78 patients were randomised in total and 67 patients remained on protocol. Treatment outcome was assessed by non-contrast CT. Stone-free rates at 4 months follow-up were 35% and 50% for ESWL and flexible URS respectively, but the difference was not statistically significant. Overall complication rates were similar (ESWL 23% Vs URS 21%). Smith DR and Patel A have commented that the Lower Pole II study has disappointingly lower stone-free rates for both modalities than was expected from previous publications, which would be attributed to the higher sensitivity of non-contrast CT to identify small and clinically insignificant fragments.

We have reviewed our local experience of RIRS for renal stones in 48 patients treated between 2004 and 2007 in our centre. 45.8% of patients have failed previous ESWL; 56.3% of patients have stone sizes less than 10mm, 37.5% have stone sizes 10 - 20mm and 6.7% have stones >20mm in size. Successful outcome (residual stone fragments <4mm in size) was achieved in 62.5% of patients and half of the patients underwent Day-surgery. Minor complications developed in 2.1% of patients.

Guidelines

ESWL and PCNL are the recommended primary treatment options for renal stones (stone size <20mm and 20mm or more respectively) in the European Association of Urology (EAU) Guidelines. Flexible URS was stated as an effective treatment for ESWL refractory renal calculi (Grade A recommendation), with reported stone-free rates of 50 - 80% for calculi <1.5cm in size, while larger stones can also be treated successfully. It was also stated in the guidelines that "because of the poor
results of ESWL for lower pole stones... flexible URS could become a reliable first-line treatment for lower pole stones < 1.5 cm. Flexible URS is also an option when ESWL might be contraindicated or ill-advised (Grade C recommendation) e.g. patients on anticoagulants, obesity, pregnancy etc.

**Large Stone Burden**

Although RIRS would be optimal for stone sizes <1.5cm, RIRS for patients with large stone burden was shown to be an effective and safe treatment option. Grasso M et al have reported their series of treating 51 patients with large stone burden (size 2cm or more). Many of these patients had co-morbid conditions that precluded or complicated standard percutaneous treatment. Treatment success was achieved in 76% of patients after primary treatment and increased to 91% after secondary treatment. Three postoperative complications occurred including pyelonephritis, prostatic bleeding and a cerebral vascular accident.

Breda A et al have recently shown that planned second-look RIRS (within 15 days) was efficacious and safe for patients with large stone burden. Overall stone-free rate was 93.3% with mean number of procedures 2.3 (2 - 4). 3 out of the 15 patients developed minor complications.

We have reported our limited local experience recently in 8 patients. Indications included anatomical problems, failed ESWL and multiple stones. Mean stone size was 17.3mm (10 - 30) and mean number of stones was three (1 - 5). Successful outcome (fragments <2mm) was achieved in all but one patient (87.5%); 5 patients underwent Day-surgery. A minor complication developed in one patient (post-op fever).

**Complications of Ureteroscopy**

A meta-analysis published by the EAU-AUA Guidelines panel has evaluated the most relevant complications of ureteroscopy - sepsis, steinstrasse, stricture, ureteric injury and urinary tract infection. The overall complication rates reported in recent literature are 5 - 9%, with a 1% rate of significant complications. Serious complications, including renal loss and death, were rare.

**Future**

**Digital Era**

In line with the high-definition era of laparoscopic surgery, ureterorenoscopy has entered the digital era recently. Humphreys MR et al have demonstrated the beauty of digital ureterorenoscopy (Fig. 4a). The distal tip objective is a CMOS imaging sensor coupled to a prism, utilising light emitting diodes as the light source, which gives the surgeon superb vision within the pelvi-calycal system (Fig. 4b&c). Further studies will be required to demonstrate whether improved vision with digital imaging in RIRS will be translated into improved outcome.
Robotics
Flexible ureterorenoscopy would exert excessive strain on the surgeon who would need to keep the endoscope in deflection(s) in order to approach the target and the operation may take hours. Robotics may be the solution to this problem. Desai MM et al have reported their ingenious design of a flexible robotic retrograde renoscopy in swine model. Remote robotic flexible ureterorenoscopy was performed bilaterally in 5 acute swine (10 kidneys). A novel 14F robotic catheter system, which manipulated a passive optical fibrescope (7.5Fr) mounted on a remote catheter manipulator was used (Fig 5). The potential advantages of Robotic renoscopy compared with conventional manual flexible ureterorenoscopy include an increased range of motion, instrument stability, and improved ergonomics. The group has also reported their first human experience in the recent World Congress of Endourology & SWL in December 2008.

Conclusion
RIRS for renal stones with flexible ureterorenoscopy and Holmium laser is an effective treatment option for ESWL refractory renal calculi; it is especially useful in situations like patients with bleeding tendency or pregnancy. It has been demonstrated that treatment of patients with large stone burden is feasible, effective and safe. The future developments of RIRS would be digital imaging to improve the quality of vision and robotics to improve manoeuvrability.

References

Fig. 5a Components of flexible robotic catheter control system (Desai MM et al. Urol 2008; 72(1): 42 - 46.)

Fig. 5b The steerable catheter system
Note: coloured catheter animation provides visual clue to the surgeon about direction the catheter tip is attempting to take. (Desai MM et al. Urol 2008; 72(1): 42 - 46.)

Fig. 5c Simultaneous fluoroscopic and endoscopic view seen by the operating surgeon intraoperatively.
Note coloured catheter animation provides visual clue to the surgeon about direction the catheter tip is attempting to take. (Desai MM et al. Urol 2008; 72(1): 42 - 46.)