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ORIGINAL PAPER

Staged single-tract minimally invasive percutaneous nephrolithotomy and flexible ureteroscopy in the treatment of staghorn stone in patients with solitary kidney

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Abstract The aim of this study was to evaluate the outcome of staged single-tract minimally invasive percutaneous nephrolithotomy (MPCNL) and flexible ureteroscopy as a minimally invasive option in the treatment of staghorn stone in patients with a solitary kidney. A total of 24 patients with staghorn stone in a solitary kidney were treated with single-tract MPCNL and flexible ureteroscopy by a single surgeon. All the patients underwent single-tract MPCNL through a 20 F tract and had most of the intrarenal calculi removed at the first stage. The second stage of retrograde flexible ureteroscopy was performed 3–5 days later, after the drainage was cleared. The preoperative patient, characteristics, stone size, operative time, renal functional status and postoperative outcomes were then evaluated. Sixteen patients were partial staghorn (66.7 %), and other eight were complete staghorn (33.3 %). The overall stone-free rate was 83.3 % after the second-stage procedures, and only four patients had significant residue. The hemoglobin drop ranged from 1.1 to 3.7 g/dl, and three patients required blood transfusion. The mean serum creatinine value was 1.7 ± 0.5 mg/dl before surgery and 1.3 ± 0.4 mg/dl at the end of the follow-up period with statistical significance ($P < 0.05$). None of the patients had increased serum creatinine, and needed dialysis at the end of the follow-up period. Staged single-tract MPCNL and flexible ureteroscopy are safe and effective for the management of staghorn stone in patients with a solitary kidney and even in patients with impaired renal functions.

Keywords Ureteroscopy · Percutaneous · Nephrolithotripsy · Calculi · Staghorn

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Introduction

Renal calculi, especially staghorn stone, are very dangerous for patients with a solitary kidney. They may cause urinary tract infection, anuria, sepsis, renal insufficiency or even death. The complete removal of the stone and maintenance of the renal function are the goals of surgical treatment.

Percutaneous nephrolithotomy (PNL), which Fernstrom and Johansson first coined in 1976, has become the prime standard for the care of staghorn stone [1]. However, PNL in the management of staghorn calculi usually requires multiple tracts. Multiple access tracts are associated with greater renal parenchymal injury, which increases the risk of bleeding and even greater discomfort. Although most bleeding situations can be managed conventionally, some cases require artery embolization. For patients with a solitary kidney, angio-embolization and renal parenchymal injury may result in permanent need for hemodialysis, especially for patients with impaired renal function before surgery. Owing to the potential risk, PNL as a treatment for patients with staghorn stone in a solitary kidney is also one of the most challenging endourological procedures.

With the development of instruments and the advancements in technology, minimally invasive percutaneous nephrolithotomy (MPCNL) and flexible ureteroscopy/holmium laser lithotripsy, which can treat large intrarenal calculi with the potential to decrease morbidity for PNL, have been reported in the most modern PNL series [2–5]. The combined use of single-tract MPCNL and flexible ureteroscopy in the treatment of staghorn stone in patients with a solitary kidney may decrease the tracts and reduce the rates of major complications than that of multi-tract PNL. To test this hypothesis, we investigated the feasibility of staged single-tract MPCNL and flexible ureteroscopy in patients with staghorn stone in a solitary kidney by evaluating stone-free rates and associated complications. To our knowledge, none of the group has specifically examined this previously.

Materials and methods

Patients

Patients with staghorn stone in a solitary kidney, who have been treated with MPCNL and flexible ureteroscopy/holmium laser lithotripsy, were recruited from April 2007 to March 2010. A total of 24 patients were identified. The function of the kidneys was assessed by dimercaptosuccinic acid renography. The causes of a solitary functioning kidney were agenesis in two cases (8.3 %), previous nephrectomy in five cases (20.8 %), and no function in the contralateral kidney in 17 cases (70.8 %). Information on the patients' age, sex, stone type, stone burden, degree of hydronephrosis, and history of urolithiasis and treatment was recorded. Radiologic assessments, including ultrasonography, abdominal radiography, intravenous urography, and/or CT were performed in all the patients. Prophylactic antibiotics were administered to all the patients, and patients with infection were treated according to the antibiogram results. According to the guidelines published by the American Urological Association (AUA), staghorn stone has two types, i.e., complete and partial. The stone surface area (mm^2) was calculated using graph paper. The two-dimensional projection of the calculus was traced on a plain film obtained in the anteroposterior view. Successful stone-free status is defined as complete clearance of the stone. Insignificant residue is defined as a residual fragment of <4 mm.

Follow up

The first follow-up was evaluated 1 month after surgery and subsequent follow-ups were conducted every 3 months. Patients were followed with blood chemistry, urinalysis, plain radiography and ultrasonography as before.

Treatment

The essential steps of the MPCNL have already been described [2]. All the procedures were performed by a single surgeon (XL) [2]. Under general anesthesia or continual epidural anesthesia, the patient was placed in a split-lower-limb position, and intravenous antibiotics were given. Under direct ureteroscopic vision, a 5 or 6 F open-ended ureteral catheter was used as a retrograde placement into the renal pelvis. The bladder was drained with a 16 F Foley catheter; the ureteral catheter was then secured to the Foley catheter. The patient was then turned to a prone position with a pack under the abdomen to minimize lumbar lordosis. Under fluoroscopic guidance and with retrograde pyelography, the urologist made percutaneous punctures with an 18 gauge coaxial needle into an appropriate calix using the "bull's-eye" technique. A posterior middle calix puncture is usually preferred. Then, a 0.035 in. hydrophilic Zebra guidewire was inserted into the collecting system. The tract was performed over the guidewire with a facial dilator (Cook Urological, Spen-cer, IN) to 20 F. A peel-away sheath (Cook Urological, Spencer, IN) was then placed over it. At the first stage, the percutaneous access number was limited to a single tract.

Nephroscopy was performed with an 8.5/12.5 F nephroscope (Lixun Nephroscope, Richard Wolf, Knittlingen, Germany). Stones were fragmented using either a pneumatic lithotripsy or holmium laser lithotripsy. The large fragments (0.3 to 0.5 cm) were extracted with a 5 F forceps (Richard Wolf, Knittlingen, Germany), and the <0.3 cm fragments were mainly pushed out with an endoscopic pulsed perfusion pump (MMC Yiyong, Guangzhou, China). Afterward, a 16 F Foley catheter as a nephrostomy tube was inserted into the patient. The ureteral catheter was maintained for better drainage.

On the second postoperative day, KUB radiography and retrograde nephrostography or noncontrast CT scan were performed. If the radiologic study did not reveal any residual stones, the ureteral catheter would be removed immediately, and the nephrostomy tube would be removed 3–5 days after the first operation. Otherwise, the tube would be left in place, and a second-stage operation should be performed 3–5 days later.

At the second stage of the operation, the patient was placed in the supine lithotomy position (Fig. 1). After the removal of the ureteral catheter, a safety guidewire was placed up to the kidney, and a 12 F ureteric access sheath (CookUrological, Spencer, IN) was placed into the proximal ureter. A 7.2 F flexible ureteroscopy (Storz, Tuttlingen, Germany) was then inserted into the collecting system to search for residual stones. A 200 um holmium laser was used for dusting the stone. A 2.2 F nitinol stone basket was used to transfer the fragments larger than 2 mm into the renal pelvis. Sometimes, for obtaining adequate distention of the renal collecting system and favor ureteroscopy, we insert small peel-away sheath (18F/16F/14F or both) into the mature percutaneous access tract to reduce the drainage

Fig. 1 The supine lithotomy position

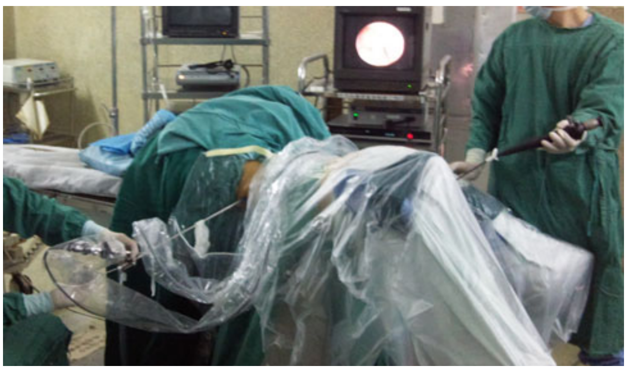

Fig. 2 Retrograde ureteroscopy and remove the stone via the pre-existing nephrostomy tract

of fluid and maintaining a satisfactory internal pressure. An 8.5/12.5 F nephroscope (Lixun Nephroscope, Richard Wolf, Knittlingen, Germany) was inserted through the pre-existing nephrostomy to clear the stone fragments (Fig. 2). At the end of the procedure, the kidney was scanned by fluoroscopy to exclude residual stone fragments. A 5 F Double-J ureter stent and a 16 F Foley nephrostomy tube were placed.

The nephrostomy tube was removed the following day, and the Double-J stent was extracted 1 month later. If the patient was considered to have a large residual stone, a second stage of flexible ureteroscopy would be performed when the Double-J stent was extracted.

Statistical analysis

Statistical analysis was done using Statistical Package for Social Sciences 13.0 for Windows. Serum creatinine was compared using the paired t test and the P value of <0.05 was considered significant.

Results

The present study included 9 males (37.5 %) and 15 females (62.5 %). The mean age of the patients was 51.25 ± 17 years (range 21–69 years). Sixteen patients were partial staghorn (66.7 %) and other eight were complete staghorn (33.3 %). The mean stone bulk was 1502.6 ± 137 mm^2 (range 512–5360 mm^2). The mean preoperative serum creatinine level was 1.7 ± 0.5 mg/dl (range 0.5–4.9 mg/dl). Eleven patients had serum creatinine values higher than 1.4 mg/dl before surgery. Most of the preoperative complications were hypertension in four patients, diabetes in three patients, and urinary infection in 11 patients. Detailed demographic and clinical data are described in Table 1.

Only two patients were rendered completely stone free after the first stage of single-tract MPNCL. The other patients required second-stage procedures through the combined use of flexible ureteroscopy and second-look MPCNL. However, in the 22 remaining patients, the average stone bulk decreased to 235.8 ± 69 mm2 after one session of MPNCL. The mean operative time was 64.2 ± 17 min (range 32–180 min) for the first stage MPCNL and 116.2 ± 33 min (range 24–173 min) for the second-stage procedures. The overall stone-free rate was 83.3 % after the second-stage procedures, including three patients with insignificant residue (<4 mm). Only four patients had significant residue. For the four patients, FU was used 1 month after the initial-stage procedure.

No major intraoperative or postoperative complications occurred. The hemoglobin drop ranged from 1.1 to 3.7 g/dl, and three patients required blood transfusion, including two patients with impaired renal function and anemia even before surgery. Four patients had fever on the first day after PNCL, which was resolved by antibiotic treatment.

The mean follow-up time was 21.3 ± 3.2 months (range of 9–38 months). The mean serum creatinine value was 1.7 ± 0.6 mg/dl before surgery and decreased to 1.3 ± 0.4 mg/dl at the end of the follow-up period with statistical significance ($P < 0.05$). An insignificant increase in the mean value of serum creatinine was observed in 11 patients with impaired renal functions. Serum creatinine values decreased to normal (range <1.4 mg/dL) in four patients. Seven patients had stable renal function with a serum creatinine level between 1.4 and 2.7 mg/dl. None of the patients had increased serum creatinine and required dialysis at the end of the follow-up period.

Discussion

Renal calculi, especially staghorn stone, are very dangerous for patients with a solitary kidney. They may cause urinary tract infection, anuria, sepsis, renal insufficiency, or even death. Complete removal of the stone and maintenance of the renal function are the goals of surgical treatment.

Table 1 Characteristics and clinical details

No. of patients	24
Average age (years)	51.25
Female/male	15/9
Cause of solitary kidney	
Agenesis	2
Previous nephrectomy	5
No function kidney	17
Stone type	
Partial staghorn	16
Complete staghorn	8
Average stone bulk (mm^2)	1502.6
Renal function	
Normal	13
Impaired	11
Mean serum creatinine (mg/dl)	1.7
Complication	
Hypertention	4
Diabetes	3
Urinary infection	11

PNL has become the prime standard of care for large (>2 cm) renal or staghorn renal stones. According to the AUA guideline report, this approach has a stone-free rate of 74–83 % [6]. With the improvement in the technique and increase in the experience of the urologists, PNL can also be used to remove calculi from special patients with a horseshoe kidney, ectopic kidney, or solitary kidney [7, 8] successfully. However, using PNL in the treatment of patients with staghorn stone in a solitary kidney poses potential risks, such as severe hemorrhage, renal parenchymal destruction, urosepsis and other major complications.

Bleeding is one of the most common and serious complications following PNL. Significant hemorrhage may occur during renal puncture, tract dilation, nephroscopy, stone dusting, or even after operation. Staghorn stone usually requires multiple access tracts for maximal stone clearance during PNL. However, multiple access tracts may be associated with greater parenchymal injury with the potential risk of bleeding. Kukreja et al. [9] reviewed the factors affecting blood loss in a prospective study of 236 patients undergoing 301 PNL procedures. They reported that the average hemoglobin drop was 1.68 ± 1.23 g/dl, and the overall blood transfusion rate was at 7.9 %. The multiple percutaneous tracts were significantly predictive of blood loss. According to El-Nahas et al. [10], a solitary kidney is another significant risk factor in predicting severe bleeding due to PNL. The authors' hypothesis is that compensatory hypertrophy is a normal physiologic response. As the thickness of renal parenchyma increases with the increase in kidney size, the puncture and dilation through thick renal parenchyma may increase the possibility of bleeding damage to move the renal tissue and its vascular supply. The blood transfusion rates for PNL of staghorn vary from 14 to 34 % [6, 11–13]. Severe hemorrhage may result in renal artery embolization or emergent nephrectomy. In patients with a solitary kidney, angio-embolization may result in permanent need for hemodialysis, especially in patients with impaired renal function even before surgery.

With the advances in flexible ureteroscopic instrumentation and holmium laser lithotripsy, URS/laser lithotripsy has become an increasingly considered option for intrarenal stone removal. For renal stones smaller than 2 cm, retrograde ureteroscopy is an excellent minimally invasive approach with lower complication rates than PNL. Recent studies have demonstrated that URS/laser lithotripsy can be used to treat internal stones larger than 2 cm. Breda et al. [14] used flexible ureteroscopy and laser lithotripsy in the treatment of 15 patients with internal calculi 20–25 mm in diameter. The stone-free rate was up to 93.3 %, and only one patient had a residual 5 mm stone fragment in the low pole of the kidney. Hyams et al. [5] used URS/holmium lithotripsy for renal stones with 2–3 cm in diameter. Among 120 patients, 76 (63 %) had a residual stone burden of 0–2 mm, and 100 (83 %) patients had a residual burden of <4 mm. However, the disadvantage of ureteroscopy is that multiple procedures may be required to clear a large stone. In addition, the endoscopic management of a large renal stone is associated with a longer operative time.

To overcome these disadvantages, the feasibility of a single-tract PNL in association with the use of flexible instruments in selected patients has been reported. Landman et al. [15] simultaneously used ureteroscopy and single-tract PCNL for nine staghorn and partial staghorn calculi. Complete stone clearance was achieved in seven of the nine (78 %) cases, and no major complications occurred. Marguet et al. [3] reported the combined use of PNL and flexible URS to treat complex renal calculi. After using flexible ureteroscopy to clear the stones in the peripheral calyces, which required a second or third nephrostomy access, the patients were placed in prone position, and single-access PCNL was performed. To conclude, staged PNL and flexible URS can effectively reduce the number of percutaneous access tracts, which would have required the management of complex and branched renal calculi and reduced potential patient morbidity and blood loss, with no significant effect on stone-free rates or operative duration. If significant ongoing bleeding persists after PNL, simultaneous flexible ureteroscopy may not be adequate for good visualization and stone manipulation. A longer operative time is necessary because of the blurred visualization. In the present study, we have chosen single-tract MPCNL and removed most of the internal calculi. The second-stage operation was performed 3–5 days later when the drainage was clear, and the retrograde flexible ureteroscopy had optimal visualization. Furthermore, the mature percutaneous access tract, which was created at the first stage, could maintain low internal pressure and facilitate disintegration or extract residual stone, which had been previously repositioned into the renal pelvis by the nitinol stone basket. Although the mean operative time was 116.2 min (range 24–173 min), the second-stage procedures seemed to last longer. The overall stone-free rate reached 83.3 % after the second-stage procedures, and only four patients had significant residue. Furthermore, no major intraoperative or postoperative complication occurred.

Based on the results of this study, the use of staged MPCNL and flexible ureteroscopy is safe and effective for the management of staghorn stone in patients with solitary kidneys. However, our results are based on a relatively small sample size; hence, further investigations are required. Furthermore, although residual fragments less than 4 mm are often defined as "insignificant" after PCNL, this is controversial and especially so in patients with solitary kidneys and should be a stricter follow-up.

Conflict of interest The authors declare that they have no conflict of interest.

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