Urol Res (2011) 39:171–176
DOI 10.1007/s00240-010-0321-2

ORIGINAL PAPER

Percutaneous nephrolithotomy for complex caliceal and staghorn stones in patients with solitary kidney

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Received: 30 October 2009 / Accepted: 1 October 2010 / Published online: 22 October 2010

Abstract Treatment of patients with solitary kidney having complex stones is one of the most challenging problem in urology. We present our experience with percutaneous nephrolithotomy (PCNL) in treating 16 patients with staghorn stones in a solitary kidney to determine long-term renal functional results. We retrospectively reviewed the records of 16 patients with complex caliceal or staghorn stones in a solitary kidney treated with PCNL. Demographic data, number and location of accesses, hemoglobin values, stone analyses, and complications were studied. Serum creatinine, glomerular filtration rate (GFR), systolic and diastolic blood pressure, new onset hypertension, and kidney morphology were determined preoperatively and postoperatively at 1 month and 1 year. Male to female ratio was 14:2 and mean age was 49.6 years (range 31–55). Of these, 10 (62.5%) patients required a single tract, while 6 (37.5%) required multiple tracts. The calculi were extracted or fragmented successfully in 13 (81.3%) patients and complete stone clearance was achieved after the first stage. In two patients with residual calculi, a double-J catheter was inserted and extracorporeal shock wave lithotripsy (SWL) was performed. There were no significant intraoperative problems except in one patient, who had bleeding from an infundibular tear attributable to torquing. During the 1-year study period, none of the patients progressed to end-stage renal disease requiring dialysis. We demonstrated a significant improvement in creatinine and GFR levels from preoperatively to 1-year follow-up. The number of patients with hypertension before PCNL was 5 and by the end of follow-up there was no new onset hypertension. The demonstrated effectiveness, small number of complications at short-term, not any poorly effect on renal function and blood pressure at the long-term follow-up confirm that PCNL is not only effective but is also safe in the solitary kidney with staghorn calculi.

Keywords Percutaneous nephrolithotomy · Solitary kidney · Staghorn stone · Creatinine

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Introduction

Staghorn calculi are branched, usually infected, stones that occupy a large portion of the collecting system, typically filling the renal pelvis and branching into several or all of the calices. An untreated staghorn calculus is likely to destroy the kidney and cause life-threatening sepsis [1]. Treatment of these stones in patients with solitary kidney is one of the most challenging problem in urology. Recently, the American Urological Association Nephrolithiasis Clinical Guidelines panel recommended percutaneous stone removal as first-line treatment for the management of staghorn calculi [2]. This approach, according to the guidelines report, is associated with a stone clearance rate of 74–83%, an acute complication rate of 15%, a transfusion rate of 14–24%, and an ancillary procedure rate of 18% and is clearly superior to extracorporeal lithotripsy monotherapy, combination therapy, and open surgery [3]. However, despite the relatively minimally invasive nature of this modality, short and long-term renal functional effects have yet to be completely defined.

In this study, we evaluated the safety and efficacy of PCNL on the treatment of complex caliceal or staghorn stones in a solitary kidney and determined long-term renal functional results. To the best of our knowledge, this study is the first series reported in the literature.

Patients and methods

We performed a retrospective analysis of 16 evaluable patients who underwent PCNL for complex caliceal and staghorn stones in a solitary kidney between November 2006 and March 2009 at the Urology Department of Kecioren Research and Training Hospital. A complete staghorn stone was defined as one that either totally filled all calyces and renal pelvis, or filled >80% of the renal collecting system. A complex calculi was defined as one that filled the renal pelvis and at least two or more calyces [4]. Stone size was assessed as the surface area and calculated according to the European Association of Urology guidelines [5]. The causes of solitary kidney were congenital in three cases (18.7%), previous nephrectomy in 11 [stone disease in 7 (43.8%), infection in 3(18.7%), and trauma in 1(6.3%)] and nonperfused contralateral kidney in 2 (12.5%).

Data were collected from the retrospective reviews of hospital and physician's office records, and by contact with the patients. Patients were evaluated with plain film, intravenous urography, ultrasonography, urinalysis, urine culture, complete blood count, serum biochemistry, and coagulation tests before the procedure. Computerized tomography was not done routinely, but was performed whenever needed. A primary metabolic workup was performed in all patients. Prophylactic perioperative wide-spectrum antibiotics were administered to patients with sterile urine, and patients with bacteriuria were treated according to the antibiogram results. The preoperative factors analyzed were age, sex, preoperative urinary tract infection, stone type, parenchymal thickness, and degree of hydronephrosis. Serum creatinine (Cr), GFR, systolic and diastolic blood pressure, new onset hypertension, and kidney morphology were determined preoperatively and postoperatively at 1 month and 1 year. Calculated GFR before and after PCNL was determined using the Cockroft and Gault formula, GFR = [(140-age) (weight in kg) (0.85 for women)]/72 × creatinine (mg/100 ml) [6, 7]. In terms of statistical analysis, patient data were analyzed using SPSS version 15, and a comparison between the parameters before and after PCNL was done using the Wilcoxon signed rank test, unpaired and paired *t* tests with differences resulting in $p < 0.05$ considered significant.

Blood pressure preoperatively and at the last follow-up was determined in an ambulatory setting with the patient seated. The operative and postoperative factors recorded were size of tract, using devices, tract number, operative time, stone free status, intraoperative and postoperative complications, nephrostomy removel time, rate of ancillary procedures, hospitalization time, and recurrence of stones during the follow-up period. In addition, patients were evaluated for anatomic and metabolic factors that could be responsible for stone formation.

The first follow-up evaluation was performed 1 month after the operation and then patients were seen every 3 months during the first year and every 6 months thereafter. At each visit, urinalysis, urine culture, serum Cr, plain film, and abdominal ultrasound were performed. If stone recurrence was diagnosed, noncontrast spiral computerized tomography was carried out.

Surgical technique

All procedures are performed with the patient under general anesthesia. A 5 or 6F ureteral catheter is placed, and the bladder is drained with a 16F Foley catheter. After ureteral catheter insertion, patients were placed in the prone position and percutaneous access was achieved under fluoroscopic guidance using an 18-gauge needle and guide wire. Tract dilatation was accomplished using Amplatz or balloon dilators of up to 22 or 30F. Fragmentation and stone removal were accomplished in all patients using pneumatic or ultrasound energy and retrieval graspers through rigid 22F–26F nephroscopes. A holmium laser and nitinol basket catheter were used through flexible nephroscopes for locations unreachable using the rigid instruments. Stone clearance was determined by a combination of fluoroscopy and rigid or flexible nephroscopy at the end of the procedure, sometimes with a plain radiograph or CT postoperatively if there was not confidence in the intraoperative assessment. The operations were completed when residual fragments were not detected on fluoroscopic imaging and rigid or flexible nephroscopic control. After completion, 16F reentry catheter or alternatively a 18F Foley catheter as nephrostomy tube was inserted in all patients. Antegrade nephrostography was routinely performed on postoperative days 2–3 and the nephrostomy tube was removed. If the patient was comfortable, afebrile, and there was no longer drainage from the nephrostomy site, patient discharged home the next day.

Results

The present study included 14 men (87.5%) and 2 women (12.5%). The mean age of the patients at receipt of the surgical procedure was 49.6 years (range 31–55 years). The mean stone burden was 10.2 cm^2 (range 6–16 cm^2). The mean preoperative serum Cr level was 1.49 mg/dl (range 0.9–2.6). Of the 16 patients, 2 (12.5%) had a serum Cr level greater than 2 mg/dl. Three (18.8%) patients, had a stone

Table 1 Patient, stone and operative characteristics

	No.	%	Mean	Range
Age (year)			49.6	31–55
Female/Male	2/14			
Stone side (left/right)	9/7			
Positive preoperative urine culture	2	12.5		
Renal intervention history	3	18.8		
Cause of solitary kidney				
Congenital	3	18.8		
Previous nephrectomy	11	68.7		
Nonperfused kidney	2	12.5		
Time to access the collecting system (min)			21.8	10–35
No. of tracts				
Single	10	62.5		
Multiple	6	37.5		
Operative time (min)			95.2	55–145
Seconder procedure requirement	3	18.8		
Initial stone-free rate	13	81.3		
Final stone-free rate	15	93.7		
Nephrostomy removel time (days)			3.9	3–7
Hospitalization time (days)			5.2	4–9
Stone analysis				
Calcium oxalate and/or phosphate	8	50		
Struvite	4	25		
Uric acid	1	6.2		
Cystine	1	6.2		
Mix	2	12.5		

intervention in same kidney (previous PCNL, one patient; previous pyelolithotomy or nephrolithotomy, two patients).

Of these, 10 (62.5%) patients required a single tract, while 6 (37.5%) required multiple tracts. Access to calices through a supracostal route was established in 5 renal units (22.8%): 2 patients had a supracostal 11th rib approach and 3, a supracostal 12th rib approach. The mean time to access the collecting system was 21.8 min (range 10–35 min) and mean operative time was 95.2 min (range 55–145 min). The stones were completely cleared in 13 patients (81.3%) after one session of PCNL, and 3 had significant residue. Of these three patients, one required a second-look procedure, 2 (12.5%) required a double-J catheter and SWL. Thus, 15 patients (93.7%) were rendered completely stone free or had insignificant residue (5 mm or less) after the final procedure. Of the remaining, 1 patient had 11 mm residue stone and was followed up. The patient, stone, and operative characteristics are presented in Table 1.

There were no significant intraoperative problems except in one patient, who had bleeding from an infundibular tear attributable to torquing. The procedure was terminated and a secondlook procedure performed 6 days later. The majority of the complications were pain, hematuria, urinary leakage after removal of the nephrostomy tube, and postoperative fever; complications are detailed in Table 2. The hemoglobin drop ranged from 0.8 to 5.2 g/dl and three patients required blood transfusion, including one in whom intraoperative bleeding obscured vision. Two patients had prolonged hospital stay because of urinary leakage from nephrostomy tract after the removal of the tube. They resolved spontaneously in 3 days without intervention. Three patients had fever on the first day after PCNL, which resolved spontaneously in one, while the remaining two patients required antibiotic treatment because of positive blood and urine cultures.

Table 2 Complications of PCNL

Postoperative fever	3 (18.8%)
Urinary tract infection	2 (12.5%)
Prolonged tract leakage	2 (12.5%)
Required blood transfusion	3 (18.8%)
Intraop bleeding, procedure aborted	1 (6.2)

During the 1-year study period, none of the patients progressed to end-stage renal disease requiring dialysis. Two patients had preoperative serum Cr levels greater than 2 mg/dl. Postoperatively, creatinine levels reached normal values (<1.5 mg/dl) in these patients and they were discharged home with stable creatinine levels. Mean Cr before PCNL in these patients was 1.49 ± 0.46 mg/dl (0.9–2.6) compared to 1.28 mg/dl (0.8–1.5) by the end of the 1-month follow-up period with statistical significance ($p = 0.05$). The same findings were observed in GFR in that before PCNL it was 75.56 ± 22.2 ml (40–110)/min and by the end of the 1-month follow-up it was 82.5 ± 15.6 ml (62–110)/min with statistical significance ($p = 0.033$). However, there were no statistically significant differences between these parameters from 1 month to 1-year follow-up ($p > 0.05$). Mean creatinine and GFR values were 1.22 mg/dl (0.7–1.7) and 84.5 ml/min (65–115) at the end of the year, respectively.

Patient groups undergoing single-tract or multiple-tract PCNL had similar preoperative serum Cr (mean, 1.47 vs. 1.53) and GFR values (mean, 76.2 vs. 74.3). After PCNL, both patients groups showed similar changes in creatinine and estimated GFR, at 1 month and 1-year follow-up period. All patients with struvite stones had normal preoperative serum Cr (<1.4 mg/dl), baseline values were significantly different in the two patients groups (strivute groups: mean Cr = 1.22 mg/dl and GFR = 82.2 ml/min versus other stones group: mean Cr = 1.58 mg/dl and GFR = 73.3 ml/min). After PCNL, both groups showed a similar fall in Cr, and rise in estimated GFR, at 1 month and 1-year follow-up period.

Table 3 Serum creatinine, GFR and blood pressure levels before and after PCNL

	Preoperative	Postoperative, 1 month	*p* value
Serum creatinine (mg/dl)			
Mean (±SD)	1.49 (0.46)	1.28 (0.22)	0.05
Range	0.9–2.6	0.8–1.5	
GFR (ml/min)			
Mean (±SD)	75.56 (22.24)	82.5 (15.65)	0.033
Range	40–110	62–110	
Mean blood pressure (mmHg)			
Systolic	132.8	127.5	0.185
Diastolic	76.8	78.1	0.248
Hypertension (no.)	5	5	

The number of patients with hypertension before PCNL was five and by the end of follow-up there was no new onset hypertension. Table 3 compares serum creatinine, systolic and diastolic blood pressure, and calculated GFR in 16 patients before and after treatment.

Discussion

An untreated staghorn calculus is likely to destroy the kidney and cause life-threatening sepsis. Complete removal of the stone is, therefore, crucial in order to eradicate any causative organisms, relieve obstruction, and prevent further stone growth [1]. Improvements in endourologic instruments, lithotripsy devices, and surgical techniques during the past two decades have resulted in greater success rates and lower complication rates for percutaneous renal surgery. PCNL has been recommended as the best first treatment option for patients with staghorn calculi by the AUA Guidelines Panel based on the superior outcomes and acceptable low morbidity [2, 8].

Major complications, although rare, can lead to significant morbidity especially in patients with solitary kidney. One of the most common and worrisome complications following percutaneous renal surgery is renal hemorrhage [9]. Bleeding may occur at any point intraoperatively to the immediate or late postoperative period and about 0.8% of the cases need angioembolization for the treatment of uncontrollable bleeding [10]. The risk of blood transfusion after PCNL is influenced by many factors, including operative technique, patient status, and stone complexity [11]. The incidence of severe PCNL associated vascular injuries was directly related to stone complexity. Kessaris et al. [12] observed staghorn stones in 8 of 17 patients (47%) who required embolization and Srivastava et al. [10] concluded that stone size significantly predicted severe vascular lesions after PCNL. El-Nahas et al. [13] reported that staghorn stones were a significant independent risk factor because during PCNL for such complex stones multiple tracts and excessive manipulation were needed. El-Nahas et al. [13], also identified that solitary kidney was a significant risk factor for bleeding because compensatory hypertrophy is a normal physiological response as the thickness of renal parenchyma increases with the increase in kidney size. It is speculated that puncture and dilation through thick renal parenchyma may increase the possibility of bleeding damage to more renal tissue and its vascular supply. In this study, hemoglobin drop ranged from 0.8 to 5.2 g/dl and three patients required blood transfusion, including one in whom intraoperative bleeding obscured vision. In our study, operator experience was a significant predictor for minimally bleeding because experienced endourologists had the skills needed to perform proper puncture, judicious dilation, and gentle manipulations using rigid and flexible nephroscopes.

The first report of the percutaneous management of staghorn calculus was by Clayman et al. [14]. Since then, several reports have been published describing experience with managing staghorn calculi. Streem et al. [15] described a combined technique in 1997 termed ‘sandwich therapy’, which consisted of primary percutaneous stone debulking followed by SWL of any inaccessible, residual infundibulocalyceal stone extensions or fragments. However, improved PCNL techniques, incorporating the increasing use of flexible nephroscopy and providing complete or nearly complete clearance of stone material at the time of the primary procedure, have decreased or eliminated the need for additional SWL treatment [16]. The target endpoint of treatment for every patient undergoing PCNL at our institution is complete calculus clearance percutaneously. SWL is reserved for the occasional patient with small residual calculi in whom percutaneous access is technically unfeasible or the patient’s general medical condition prohibits the use of additional percutaneous sessions. Also, we agree that flexible nephroscopy and ureteroscopy, either concomitant with or subsequent to the initial surgery, have increased the stone-free rate and decreased the morbidity of percutaneous renal surgery. The concept of PCNL and the use of flexible nephroscopy were initially published by Wong and Leveillee in 1992. Wong and Leveillee in their series described a stone-free rate of 95% in patients treated with single percutaneous tract with flexible nephroscopy [17]. Undre et al. [18] assessed the use of flexible instruments through percutaneous and retrograde approaches. They present a case of ‘pass the ball’, helpful in tackling large, complex, or branched staghorn calculi without the need for multiple percutaneous punctures, removing larger fragments. The authors’ hypothesis is that the technique combines the advantages of PCNL and flexible ureteroscopy effectively decreasing the number of tracts required in complex stones. They conclude that this effectively reduces the potential morbidity and discomfort associated with the multiple tracts without compromising on stone free rates. In our study, 10 (62.5%) patients required a single tract, while 6 (37.5%) required multiple tracts. There were no significant intraoperative problems except in one patient, who had bleeding from an infundibular tear attributable to torquing. The majority of the complications were pain, hematuria, urinary leakage after removal of the nephrostomy tube, and postoperative fever. The stones were completely cleared in 13 patients (81.3%) after one session of PCNL. One patient required a second-look procedure, 2 (12.5%) required a double-J catheter and SWL. 15 patients (93.7%) were rendered completely stone free or had insignificant residue (5 mm or less) after the final procedure.

Despite the relatively minimally invasive nature of PCNL, long-term renal functional effects have yet to be completely defined in solitary kidney. In 1986, Streem et al. reported no difference in serum creatinine at 1 month in 5 patients with a solitary kidney who were undergoing PCNL [17]. In 2002, Liou and Streem reported no significant change in estimated creatinine clearance in a comparison of percutaneous therapy, SWL and combination therapy for stones in patients with a solitary kidney [19]. Serum creatinine, blood pressure, and calculated glomerular filtration rate were determined before and after treatment, and there was no significant difference between any of the parameters before and after SWL and PCNL. In a study of 15 patients with a normal contralateral kidney, Mayo et al. [20] found improved function in the subset with infected stones. Handa et al. reported that a single PCNL procedure in humans and animals produces a small but permanent parenchymal scar at the site of the nephrostomy tract after several weeks [21]. This injury, and any associated interstitial inflammation, may resolve, but may also progress to fibrosis and scarring extending large distances away from the tract. It is not yet known whether the punctured papilla is able to regain its normal function over time [9]. It seems that multiple-tract PCNL may magnify the loss of parenchymal tissue, with resultant diminished global renal function, but there are at present no available well-constructed trials comparing the long-term renal effects of multiple-tract PCNL with single-tract PCNL. In our study, we demonstrated a significant improvement in creatinine and GFR levels from preoperatively to 1-month follow-up. Mean creatinine before PCNL in these patients was 1.49 ± 0.46 mg/dl (0.9–2.6) compared to 1.28 mg/dl (0.8–1.5) by the end of the 1-month follow-up period. The same findings were observed in GFR in that before PCNL it was 75.56 ± 22.2 ml (40–110)/min and by the end of the follow-up it was 82.5 ± 15.6 ml (62–110)/min. However, there were no statistically significant differences between these parameters from 1 month to 1-year follow-up. We believe that the most deleterious effect on renal function is neglected obstruction. If obstruction in a solitary kidney is rapidly relieved the kidney will regain basal function.

For renal stones smaller than 2 cm, retrograde ureteroscopy (URS) is an excellent minimally invasive approach with high reported stone-free rates. Improvements in ureteroscope flexibility and diameter as well as ureteroscope accessories and techniques have resulted in more efficient and complete treatment of stones throughout all renal calyces. In the recent literature, there are in creasing reports of endoscopic URS as a viable treatment for large renal calculi [21–23]. Stone-free rates of 77–91% have been cited, which are comparable to PCNL rates. [21–23] A disadvantage of URS is that multiple procedures may be required to clear a large stone, whereas PCNL can provide high stone-free rate after the first treatment. We think that the flexible URS with a holmium laser may be an effective alternative therapy to PCNL for a single intrarenal calculus 2 cm or greater in select patients. URS is known to have fewer overall complications compared to PCNL[24]. However, we do not know the long-term follow-up of retrograde flexible ureteroscopy in the treatment of large renal stones in patients with solitary kidney and currently PNL remains the gold standard treatment for large intrarenal stones in this group.

The demonstrated effectiveness, small number of complications at short-term, not any poorly effect on renal function and blood pressure at the long-term follow-up confirm that PCNL is not only effective but is also safe in the solitary kidney with staghorn calculi.

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