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The Impact of Percutaneous Nephrolithotomy in Patients with Chronic Kidney Disease

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Abstract

Introduction: The impact of percutaneous nephrolithotomy (PCNL) in chronic kidney disease (CKD) patients was retrospectively analyzed in this study. We analyzed the factors that can impair renal function and predict the need for renal replacement therapy (RRT) after PCNL.

Patients and Methods: Ninety-one chronic kidney patients with a mean age of 52.5 ± 13 involving 117 renal units underwent PCNL in our institution for 5 years. A mean of 1.6 ± 1.1 tracks and 1.3 ± 0.6 sittings per renal unit was required for PCNL. The estimated glomerular filtration rate (eGFR) pre-PCNL (postdrainage), peak eGFR on follow-up, and eGFR at last follow-up were recorded. The CKD stage pre-PCNL was compared with the CKD stage at last follow-up.

Results: Complete clearance, auxiliary procedure, and complication rates were 83.7%, 2.5%, and 17.1%, respectively. The mean eGFR pre-PCNL and peak eGFR at follow-up were 32.1 ± 12.8 and 43.3 ± 18.8 mL/minute/1.73 m^2, respectively ($p < 0.0001$). At a mean follow-up of 329 ± 540 days, deterioration with upmigration of CKD stage was seen in 12 patients (13.2%). Eight patients (8.8%) required RRT in the form of either maintenance hemodialysis or renal transplantation. Postoperative bleeding complication requiring blood transfusions was seen in seven (5.9%) and two (1.7%) of the renal units subsequently required super selective angioembolization. There were two mortalities in the postoperative period. Postoperative complications and peak eGFR (less than 30 mL/minute/1.73 m^2) at follow-up are two factors that predict renal deterioration and RRT. Renal parenchymal thickness (<8 mm) also predicts the need for RRT.

Conclusion: PCNL has a favorable impact in CKD patients with good clearance rates and good renal functional outcome. PCNL in this high-risk CKD population is to be done with care and full understanding of its complications.

Introduction

Renal stones are an important risk factor for chronic kidney disease (CKD) in the general population.[1] The prevalence of urinary stone disease in patients on maintenance hemodialysis is reported to be 3.2%,[2] and 1.9% to 7.7% of the patients who undergo percutaneous nephrolithotomy (PCNL) have CKD.[3,4] The treatment for renal stones in patients with CKD should be effective so that renal function improves or further renal deterioration does not occur with stable renal function. This stable phase can avoid the need for renal replacement therapy (RRT). The impact of PCNL in patients with CKD was assessed in this retrospective evaluation.

Patients and Methods

Stone removal with consequent relief of obstruction and infection can avoid RRT. Our treatment strategy involves draining all hydronephrotic kidneys with percutaneous nephrostomies (PCN). The nephrostomy tubes are placed strategically with careful planning, so that the matured tracts can be used for future PCNL. Multiple nephrostomy tubes may be required for adequate drainage of all calyces. Urine obtained at the time of nephrostomy is sent for culture and sensitivity. Urinary tract infection is treated with appropriate antibiotics. Nephrologist's help is obtained for correction of fluid overload, electrolyte imbalances, acidosis, and anemia. Appropriate temporary RRT may also be initiated if required.

During PCNL the number of tracks used is kept to an optimal minimum. We routinely use Amplatz sheath after track dilatation so as to keep the intrapelvic pressures low. The nephroscopy time usually does not exceed 1 hour in these high-risk patients. Nephrostomy drainage and antegrade Double-J stents are placed if indicated. In the postoperative

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period, the patient is monitored for hemodynamic stability, electrolyte imbalances, acidosis, and fluid overload.

We analyzed our data of 1990 adult patients who underwent PCNL for renal stones in the last 5 years till 2008. To eliminate the element of acute renal obstruction as a cause of elevated creatinine, the patients with evidence of obstruction were drained with PCN for an adequate period till nadir serum creatinine (a minimum of two equal lowest values) was reached. Any associated infection was treated with antibiotics. Ninety-one patients who were adequately drained with nephrostomies or not obstructed and persisted to have a serum creatinine >1.5 mg/dL were included in this study. Paediatric patients (age <18) were excluded from this analysis.

All patients were assessed preoperatively by a detailed history, physical examination, laboratory, and radiological evaluation. Laboratory evaluation included urine analysis and culture, basic hematology, and serum biochemistry. All patients were evaluated with plain X-ray and ultrasound of the kidney, ureter, and bladder region. However, noncontrast computed tomography scan with three-dimensional reconstruction is now our choice of imaging in patients with renal insufficiency.

Details on patient's age, sex, weight, comorbidity, presenting clinical features, and significant medical and surgical history were recorded. Pre-PCNL interventions like insertion of PCN, Double-J stent, and hemodialysis were noted. Intraoperative details like number of tracks, number of sessions, hemoglobin drop, and complications including blood transfusion were evaluated. Auxiliary procedures for removal of residual stones and other procedures for management of complications were recorded. The follow-up data were scrutinized for episodes of recurrent urinary tract infection, stone recurrences, auxiliary procedures, and the requirement of maintenance RRT.

Serum creatinine was recorded on the morning before surgery (pre-PCNL), at discharge and on every follow-up visit. The estimated glomerular filtration rate (eGFR) was calculated using the four-variable modification of diet in renal disease (MDRD) equation.[5,6] The pre-PCNL eGFR, peak eGFR, and eGFR at last follow-up were recorded. The five-stage classification of CKD as per the National Kidney Foundation published guidelines was used in our study. Patients with CKD stages 1–5 are defined as atients of chronic kidney damage with normal, mild, moderately, and severely decreased GFR of $\geq$90, 60–89, 30–59, 15–29, and <15 mL/minute/1.73 m^2, respectively.[7] The CKD stage pre-PCNL was compared with the CKD stage at last follow-up. Any patient who migrated to a higher or lower stage was classified as deteriorated or improved, respectively. A patient who continues to be in the same stage was classified as stable.

Multivariate analysis was done to evaluate the factors that predict renal deterioration as well as the need for RRT. Statistical analysis was done using SPSS software version 15. Multiple regression analysis using backward elimination method for variables was used.

Results

The mean age of the 91 patients studied was 52.5 ± 13. The male-to-female ratio was 6.8:1. Pain was the commonest (60.7%) presenting symptom. The other presenting features included uremic symptoms, fever, lower urinary tract symptoms, decreased urine output, hematuria, pyuria, and graveluria. Renal stones were located on the left side, right side, and bilaterally in 35, 30, and 26 patients, respectively. Of the 117 renal units, PCN were placed in 91 renal units (77.8%) in view of hydronephrosis. The average number of days with nephrostomy drainage was 9.4 ± 7.5 before PCNL. Thirteen patients (14.3%) required pre-PCNL hemodialysis. The mean pre-PCNL eGFR assessed on the morning of procedure after adequate period of drainage in those patients with hydronephrosis was 32.1 ± 12.8 mL/minute/1.73 m^2. The stones were solitary renal stones in 42.7%, staghorn stones in 18%, and multiple stones in 39.3%. The mean stone size was 758.5 ± 864.2 mm^2 (range 50–5040 mm^2). Twenty-two patients (24.2%) had solitary functioning kidneys. Apart from the 26 patients who presented with bilateral renal stones, another 34 patients gave a history of contralateral stone disease in the past which required surgical intervention. Past procedures for removal of stones were done in 25 of the 117 renal units. The procedures included pyelolithotomy, PCNL, and extracorporeal shock wave lithotripsy. Comorbid conditions included diabetes mellitus in 6 patients, hypertension in 18 patients, and both diabetes and hypertension in another 10 patients. Ischemic heart disease and chronic obstructive airway disease were seen in four and one patients, respectively.

Complete clearance defined as nonvisualization of residual fragments in X-ray and ultrasonography at 1 month after PCNL was achieved in 98 renal units (83.7%). Most of the renal units required removal of the stones in multiple stages with a mean of 1.3 ± 0.6 stages per renal unit. Multiple tracks were required with a mean of 1.6 ± 1.1 for complete removal of stones. The mean hemoglobin drop was 1.8 ± 1.1 gm/dL. Shock wave lithotripsy as an auxiliary procedure was required for clearance of residual stones in 2.5%.

Complications were seen after PCNL in 20 renal units (17.1%). Postoperative bleeding complication requiring blood transfusions seen in seven (5.9%) and two (1.7%) of the renal units subsequently required super selective angioembolization. Urinary tract infection defined as culture proven or prolonged febrile episodes were seen in nine patients (7.7%). Fluid overload requiring urgent hemodialysis and a perinephric urinoma requiring ultrasound-guided aspiration were seen in one patient each. There were two mortalities in the postoperative period, one elderly hypertensive man with known coronary disease to myocardial infarction and another elderly lady succumbed to sepsis and shock. Blood transfusions were required in 20.5% of the patients. These include blood transfusions given both pre- and post-PCNL. Most of these blood transfusions were given to the patients preoperatively because of the preexisting anemia in these CKD patients.

After PCNL the patients were discharged after mean hospital days of 7.3 ± 4.4. They were regularly followed up in the outpatient department. The corresponding peak eGFR on follow-up was noted along with the days taken to achieve the same. The mean peak eGFR achieved on follow-up was 43.3 ± 18.8 mL/minute/1.73 m^2 at a mean of 82 ± 143 days ($p < 0.0001$). The mean eGFR at last follow-up at a mean period of 329 ± 540 days decreased marginally to 38.7 ± 20.7 mL/minute/1.73 m^2 ($p = 0.06$) (Fig. 1).

Stone analysis using X-ray diffraction technique was available for stones from 27 renal units. Calcium oxalate stones formed the majority with 82%, followed by struvite

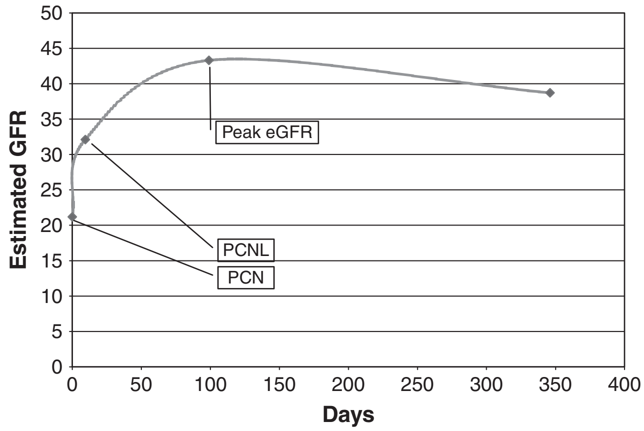

FIG. 1. The graph depicts the trend of mean estimated glomerular filtration rate (eGFR) following relief of obstruction and stone removal in patients with chronic kidney disease.

(11%) and uric acid stones (7%). Stone recurrences were detected in seven patients (7.6%) on follow-up after a mean post-PCNL period of 3.7 ± 1.9 years. Recurrent urinary tract infections requiring treatment were seen on follow-up in 28 patients (30.8%).

At a mean follow-up of 329 ± 540 days, renal functional improvement with CKD stage down-migration was seen in 32 patients (35.2%) and stabilization of renal function with no change in CKD stage was seen in 47 patients (51.6%). Deterioration with up-migration of CKD stage was seen in 12 patients (13.2%) (Table 1). Eight patients (8.8%) required RRT in the form of either maintenance hemodialysis or renal transplantation.

Clinical factors were evaluated for their ability to predict renal deterioration and RRT (Table 2). The factors that predict renal function deterioration include postoperative complications and peak eGFR at follow-up. Multivariate analysis was also done with the same clinical factors to predict RRT in future. The factors that predict RRT are renal parenchymal thickness, postoperative complications, and peak eGFR at follow-up. Renal parenchymal thickness <8 mm predicted RRT with an accuracy of 77.8%. The peak eGFR of <30 mL/minute/1.73 m^2 predicted RRT with an accuracy of 78.6%.

Discussion

Stones in the urinary tract cause renal damage because of resultant obstruction, infection, frequent surgical interventions, and coexisting medical disease.[8–10] Deposition of calcium oxalate crystals in the interstitium can also cause fibrosis.

Table 1. Chronic Kidney Disease Stage Migration Following Percutaneous Nephrolithotomy

CKD stage at last follow-up	5	4	3	2	1
1					
2			15 (29.4%)	1 (100%)	
3	2 (22.2%)	13 (43.3%)	30 (58.8%)		
4	2 (22.2%)	11 (36.7%)	4 (7.8%)		
5	5 (55.6%)	6 (20%)	2 (3.9%)		

CKD stage pre-PCNL

CKD = chronic kidney disease; PCNL = percutaneous nephrolithotomy.

Patients with CKD are anemic with impaired platelet function. There is an increased tendency for bleeding during surgical interventions. They are also more susceptible to infection. Their body homeostasis is impaired with resulting electrolyte imbalances and fluid overload. Depending on the duration and severity of CKD, secondary hyperparathyroidism, renal osteodystrophy, altered lipid profile, and cardiomyopathy are added problems. Patients with CKD are thus at a high risk for any form of anesthesia and surgery.[11]

In our study we have used the four-variable MDRD equation to calculate the eGFR. The four-variable MDRD equation is comparable to the six-variable equation, which also includes serum albumin and urea nitrogen. The four-variable equation is excellent in both health and disease.[5,6]

Agrawal et al published their experience with PCNL in 78 patients with calculous nephropathy and advanced renal failure. An improvement in renal function was seen in 64 patients, whereas in the remaining 11 patients the renal function remained same or deteriorated. The initial renal functional evaluation in this study was taken at presentation rather than after placing PCN and treating the infection to rule out the component of acute failure. Complications were seen

Table 2. Clinical Factors Predicting Outcome

	p-*Value predictive of renal deterioration*	p-*Value predictive of renal replacement therapy*
Preoperative factors		
Clinical presentation—fever	0.348	0.586
Clinical presentation—pain	0.756	0.264
Sex	0.503	0.145
Comorbid conditions	0.232	0.241
Previous procedure	0.549	0.812
Pre-PCNL urinary tract infection	0.719	0.251
Hydronephrosis	0.807	0.787
Renal parenchymal thickness	0.145	0.041[a]
Percutaneous nephrostomy drainage	0.298	0.68
Period of nephrostomy drainage	0.604	0.944
eGFR pre-PCNL (post-deobstruction)	0.163	0.529
Staghorn/multiple/solitary	0.481	0.585
Stone surface area	0.807	0.743
Intraoperative factors		
Unilateral/bilateral PCNL	0.132	0.527
Tracks	0.746	0.415
Sittings	0.98	0.409
Complete clearance	0.941	0.698
Intraoperative complication	0.273	0.921
Postoperative factors		
Hemoglobin drop	0.155	0.733
Postoperative complications	0.034[a]	0.009[a]
Follow-up factors		
Peak eGFR on follow-up	0.0001[a]	0.0001[a]
Days to peak eGFR	0.196	0.083
Stone recurrence	0.29	0.769
Recurrent infections	0.529	0.394

[a]*p*-value <0.05 is significant.
eGFR = estimated glomerular filtration rate.

in 13.3% of the patients. Septic complications were seen in eight patients out of whom three died despite intensive treatment. They concluded in their analysis that patients with severe azotemia, pyonephrosis, and reduced parenchymal thickness are unlikely to show improvement in renal function.[3]

Kukreja et al in 2003 presented the data on the progression of renal function in CKD patients with renal stones after PCNL in 84 patients. Patients with acute renal failure were excluded from the study. Serum creatinine rather than eGFR was used to measure renal function. Paediatric population was included in the study. The patients in the study were classified as improved, stabilized, or deteriorated depending upon the percentage variation in follow-up serum creatinines. The factors predicting deterioration in renal function were proteinuria (>300 mg/day), atrophic cortex (<5 mm), recurrent urinary tract infection, stone bulk (>1500 mm^2), and paediatric age group.[4] Our current analysis of 5 years from 2003 has significantly improved the functional outcomes of 86.8% compared with the 67.9% in their study period of 10 years from 1991. To a certain extent this improvement may be attributed to our better understanding of the impaired functioning kidney, safe techniques, and diligent follow-up of these patients for infection and recurrence.

In our study majority of the patients were in CKD stages 3 and 4 (81 of the 91 patients). Majority of the patients benefited after PCNL with improved or stabilized renal function. Improved renal function after PCNL was seen in 35.2% of the patients, even if a nephrostomy tube had already been placed. Additional nephrostomy tubes are sometimes placed to ensure that all calyces are effectively drained. Despite all these efforts nephrostomy tubes may not optimally drain all calyces especially in the presence of complex stones. Apart from that another probable reason why eGFR improves significantly after PCNL is that the focus of infection is also eradicated with complete stone removal.

Complication and blood transfusion rates are comparable to those published in the literature.[12] The peak eGFR post-PCNL on follow-up is a parameter that can predict both renal deterioration and the need for RRT. Postoperative complications mainly infection and bleeding predicts both renal deterioration and the need for RRT. Renal parenchymal thickness was another parameter that predicted the need for RRT. A significantly reduced parenchymal thickness signifies an atrophied cortex indicating extensive glomerular and tubular functional loss. Canes et al in their study of variables predicting the functional improvement or deterioration of function of a solitary kidney after PCNL found the improvement in postoperative eGFR to be predictive of improvement of renal function.[13]

An aggressive approach in our analysis with multiple tracks and sessions does not adversely affect the renal function. All efforts should be made to completely clear the stones so as to eradicate foci of infection and residual fragments causing obstruction in future. Prior nephrostomy drainage is essential as it improves the renal function, reduce existing infection, and create a mature track that decreases bleeding episodes during PCNL. Staging of PCNL is mandatory so as to keep the nephroscopy time low. The pelvic component of the stone is tackled before the calyceal component as it causes earlier complete relief of obstruction. An Amplatz sheath is used to reduce the renal pelvic pressures. Reduced pelvic pressures decrease fluid absorption and bacteremia.

Postoperative complications mainly infective and bleeding complications significantly affect the long-term outcome. Efforts to reduce the bleeding complications may include ultrasound-guided punctures, use of balloon dilatation, reduce and optimize the operating time, and stage the procedures in case of large stone burden. Reducing the track size in nonhydronephrotic systems and those with narrow infundibulums, and secondary tracks in a multiple track procedure may also reduce blood loss during PCNL.[14]

Steps to avoid postoperative infection include adequate pre-PCNL drainage of the pelvicalyceal system and administration of sensitive antibiotics preoperatively to reduce the preexisting infection. Complete clearance of all stones is essential to remove all foci of infection. Use of Amplatz sheath with resultant-reduced pelvic pressures may decrease incidence of bacteremia in patients with infective stones.[15,16] Careful postoperative irrigation through the nephrostomy drain or through a retrograde ureteric catheter for those patients with infection stones in the postoperative period may reduce the bacterial load in the pelvicalyceal system. If intrapelvic pressures rise during irrigation it may result in bacteremia.[17,18] Needless to say, efforts should also be taken to reduce hospital-acquired infections.

Conclusions

PCNL has a favorable impact in these CKD patients with good clearance rates, good renal functional outcome, and low auxiliary procedure rate. The renal function of 86.8% of the patients improved or stabilized after PCNL. The patients with CKD are a high-risk group and PCNL has its share of complications. The treating team should have the facility and expertise to manage the complications. The peak eGFR after PCNL is an important predictor of both renal deterioration and need for RRT. A good understanding of the impaired functioning kidney, safe operative techniques, prevention of complications, strict follow-up to prevent recurrent infections, and stone recurrence will go a long way in sustaining the renal functions in these patients.

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Disclosure Statement

No competing financial interests exist.

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Abbreviations Used

CKD = chronic kidney disease
eGFR = estimated glomerular filtration rate
MDRD = modification of diet in renal disease
PCN = percutaneous nephrostomies
PCNL = percutaneous nephrolithotomy
RRT = renal replacement therapy