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Effect of Multiple Access Tracts During Percutaneous Nephrolithotomy on Renal Function: Evaluation of Risk Factors for Renal Function Deterioration

Amr S. Fayad, MD,[1] Mohamed G. Elsheikh, MD,[1] Ashraf Mosharafa, MD,[1] Ragheb El-Sergany, MD,[1] Mohammed A. Abdel-Rassoul, MD,[1] Ahmed Elshenofy, MD,[1] Hisham Ghamrawy, MD,[1] Ahmed Abd El Bary, MD,[2] and Tarek Fayad, MD[3]

Abstract

Purpose: To assess the impact of multiple access tracts during percutaneous nephrolithotomy (PCNL) on short- and midterm renal function, and to determine risk factors predicting renal function deterioration and/or recoverability.

Patients and Methods: Patients undergoing PCNL with multiple punctures were prospectively enrolled. Preoperative evaluation included dimercaptosuccinic acid and diethylenetriaminepentaacetic acid renography. Patients were classified according to baseline renal function into patients with normal (<1.4 mg/dL) serum creatinine (group A) and patients with elevated (≥1.4 mg/dL) serum creatinine (group B). Patients were followed with serial serum creatinine evaluations and a repeated renography at 12 months. Factors evaluated for possible impact on renal function changes included preoperative renal function, number of access tracts, hypertension, and diabetes mellitus.

Results: There were 102 patients 21 to 65 (mean 39.9) years who completed the study. Fifty patients (group A) had normal preoperative serum creatinine levels and glomerular filtration rate (GFR), which showed no statistically significant change 12 months after PCNL. Fifty-two patients had baseline renal impairment (group B), and they experienced statistically significant worsening of the serum creatinine level and GFR at 12 months postoperatively ($P < 0.001$). Ten (19.23%) patients in group B had a significant deterioration of GFR more than 25%. Independent risk factors for this poor outcome were elevated (≥1.4 mg/dL) preoperative serum creatinine level, diabetes, and hypertension.

Conclusion: PCNL with multiple tracts carries a risk of adversely affecting renal function. Preoperative baseline renal impairment, diabetes, and hypertension are risk factors for significant renal function deterioration after the procedure.

Introduction

Percutaneous nephrolithotomy (PCNL) is the recommended treatment modality for most patients with large or complex renal stones and for staghorn calculi. PCNL-based approaches in these patients afford better outcomes than shockwave lithotripsy (SWL) and lower complications compared with open surgery.[1] With increasing stone burden and complexity, there may be a need for placement of multiple access tracts to achieve better stone clearance. Many urologists, however, hesitate to place more than one access tract during PCNL because of the potential increase in complications.[2]

Whether the placement of multiple renal punctures during PCNL affects renal function and to what degree is still controversial. Furthermore, whether there are risk factors that could impact renal recoverability after multiple renal punctures during PCNL is still not clear. In the current study, we attempt to assess the short- and medium-term impact of PCNL with multiple access tracts on renal function, as well as determine risk factors for renal function deterioration after the procedure.

Patients and Methods

Patients with renal stones undergoing PCNL with multiple access tracts were prospectively enrolled between July 2009 and February 2011. All patients gave a formal written consent before enrollment in the study. Institutional Review Board approval was obtained for the study. Exclusion criteria

[1]Department of Urology, Faculty of Medicine, Cairo University, Cairo, Egypt.
[2]Department of Urology, Faculty of Medicine, Beni Sweif University, Beni Sweif, Egypt.
[3]Department of Nephrology, Faculty of Medicine, Cairo University, Cairo, Egypt.

included bilateral renal stones, pediatric patients, and patients with congenital renal anomalies (horseshoe kidney or pelvic kidney). Multiple tracts were planned preoperatively based on the site and the size of the renal stones and their distribution within the kidney based on the preoperative spiral CT. Our aim was to clear all stones with the least possible number of punctures. Multiple punctures were planned in several cases, but during the procedure, we found out that we could completely clear the stones from a single puncture and accordingly, these cases were excluded from the study.

All patients underwent abdominal ultrasonography, plain radiography of the kidneys, ureters, and bladder (KUB) and multislice spiral CT together with radioisotopic renal study by dimercaptosuccinic acid and diethylenetriaminepentaacetic acid (DTPA) before PCNL. We used a modification of the Schlegel program developed by Gates that involves computer analysis of scintigraphic images of the kidneys after a single intravenous injection of 99mTc DTPA to measure the glomerular filtration rate (GFR). Patients were classified according to baseline renal function into group A with normal (<1.4 mg/dL) and group B with elevated (≥1.4 mg/dL) serum creatinine.

All patients underwent PCNL in the prone position under general anesthesia. Localization and proper selection of the puncture sites were aided by opacification of the collecting system by contrast injection through the ureteral catheter placed at the beginning of the procedure. Dilation of the tract was performed using Alkan dilators up to 30F. After tract dilation, nephroscopy was performed with stone fragmentation using the pneumatic lithotripter (Swiss Lithoclast).

All patients were followed up with serum creatinine and postoperative KUB radiographic evaluation within the next 24 hours. Four weeks after discharge, patients had follow-up KUB radiography, abdominopelvic ultrasonography, serum creatinine determination, urine analysis, and culture and sensitivity if indicated. These investigations were repeated at 12 months. The radioisotope scan was repeated 1 year after PCNL to assess the size of the kidney, scarring, and for GFR estimation and assessment of split and overall renal function. Patients with residual sizable renal stones who needed SWL and patients who did not complete the 1 year follow-up were excluded from the study.

Factors evaluated for possible impact on renal function included age, sex, preoperative serum creatinine level, preoperative GFR, number of access tracts, hypertension, and diabetes mellitus. Paired *t* test, General Linear Model Repeated Measures, chi-square, and logistic regression procedures were used as appropriate; *P* value ≤0.05 was found to be of statistical significance.

Results

From a total of 120 patients who underwent PCNL with multiple (2–4) access tracts, only 102 completed the study. Thirty-four patients were initially excluded from the study after performing single puncture unlike the initial plan. We took 12 patients back to the operating theater to remove residual fragments that were accessible from the same tract without any new punctures in 10 patients while 2 patients needed another puncture. Sizable residual stones not removable by second-look PCNL were found in eight patients of group A and seven patients of group B. These 15 patients were excluded from the study because they needed SWL to clear the stones. Three patients were lost to follow-up and were excluded from the study.

Patients were divided into two groups according to their preoperative serum creatinine values. Fifty patients had normal (<1.4 mg/dL) preoperative serum creatinine (group A), while 52 patients had baseline renal impairment with elevated (≥1.4 mg/dL) serum creatinine (group B). Patient characteristics are described in Table 1.

Intraoperative complications occurred in 39 (38%) patients and included intraoperative bleeding in 25 patients and perforation and/or extravasation in 14 patients. The most frequent postoperative complication was fever in 32 patients.

Group A patients had no statistically significant change in serum creatinine level after PCNL, with the mean (standard deviation [SD]) preoperative serum creatinine level of 1.02 (±0.19) mg/dL remaining relatively stable postoperatively at 1 week (1.03 [±0.161] mg/dl), 1 month (1.01 [±0.123] mg/dL), and at 12 months (0.97 [±0.126] mg/dL) ($P=0.14$), while there was a statistically significant decrease in GFR of the affected renal unit (mean preoperative GFR of 57.9 [±11.1] mL/min dropped to 53.8 [±11.4] mL/min at 12 months postoperative) ($P=0.001$).

Group B patients experienced a statistically significant increase of serum creatinine from a mean (SD) of 2.30 (±0.36) mg/dL preoperatively to 2.58 (±0.495), 2.59 (±0.4239), and 2.65 (±0.423) mg/dL at 1 week, 1 month, and 12 months postoperatively, respectively ($P<0.001$). There was also a

Table 1. Preoperative Patient Characteristics

	Group A *Serum creatinine <1.4 mg/dL*	*Group B* *Serum creatinine ≥1.4 mg/dL*
Number of patients	50	52
Mean age (range) in years	39.9 (35–76)	40.3 (26–65).
Mean (range) serum creatinine mg/dL	1.016 (0.6–1.3)	2.29 (1.7–3.2)
Mean (range) preoperative GFR mL/min.	57.94 (35–76)	39.38 (26–52)
Male: female	36 (72%):14 (28%)	34 (66%):18 (34%)
Diabetes mellitus	11 (22%)	25 (48%)
Hypertension	6 (12%)	21 (40%)
No. of access tracts 2	27 (56%)	30 (58%)
3	23 (44%)	21 (40%)
4		1 (2%)

GFR = glomerular filtration rate.

Table 2. Effect of Diabetes on Serum Creatinine and Glomerular Filtration Rate

	Nondiabetic patients (n = *66*)		*Diabetic patients* (n = *36*)	
	Preoperative	*12 months postoperative*	*Preoperative*	*12 months postoperative*
Mean serum creatinine (±SD) mg/dL	1.52 (±0.65)	1.58 (±0.81)	1.9 (±0.52)	2.24 (±0.76)
Mean GFR (±SD) mL/min	50.4 (±12.5)	46.0 (±13.3)	45.4 (±13.1)	38.1(±14.1)

SD = standard deviation; GFR = glomerular filtration rate.

statistically significant decrease in GFR from 39.4 (±6.0) mL/min preoperatively to 32.9 (±6.3) mL/min at 12 months postoperatively ($P < 0.001$).

In both groups, patients with diabetes experienced more rise in serum creatinine and more drop in GFR compared with patients without diabetes. The rise in serum creatinine and the drop in GFR was found to be statistically significant when comparing diabetic with nondiabetic patients ($P = 0.001$) (Table 2).

Patients with hypertension were also more likely to have more increase in serum creatinine value and a larger decrease in GFR, compared with patients without hypertension. These changes were found to be statistically significant when comparing hypertensive with normo-tensive patients ($P = 0.002$) (Table 3).

Ten (19.23%) patients in group B had a significant deterioration in GFR (a decrease of >25% from baseline). A multivariable analysis using a logistic regression model was used to determine if any of the following potential risk factors was associated with this particularly poor outcome: age, sex, elevated preoperative serum creatinine level (≥1.4 mg/dL), diabetes, hypertention, and number of access tracts (two *vs* three).

The independent risk factors identified as predictors of a deterioration in GFR of >25% from baseline were elevated preoperative serum creatinine level (coefficient 6.41, $P = 0.009$), diabetes (coefficient 2.85, $P = 0.025$), and hypertension (coefficient 2.79, $P = 0.05$).

Table 4 shows the distribution of patients according to chronic kidney disease (CKD) stage preoperatively and detailing the changes in the stages after the PCNL procedure. The largest movement across stages (patients having renal function changes leading to reclassification to another CKD change) was seen in CKD stage 3 (moderately reduced renal function) where of 32 patients, 13 (40.6%) had a worsening of estimated GFR 1 year after the procedure with reclassification to CKD stage 4 (severely reduced renal function) (Table 4).

Discussion

Despite the established efficacy and widespread performance of percutaneous renal surgery, the impact of multiple punctures during PCNL continues to be of significant concern. A number of pertinent questions remain without conclusive answers, despite various studies reported in the literature, such as: how safe are multiple punctures and how do complications compare with single access procedures? What are the possible effects of a more complex PCNL intervention with multiple access tracts on short- and long-term renal function? What are the factors that portend a poor outcome with multiple-tract PCNL?

The accuracy of the renal scan depends mainly on the method used to calculate clearance. Plasma clearance appears to be the most accurate; however, it necessitates multiple blood samples. Gamma camera techniques appear less accurate than plasma methods, yet the main advantages of the gamma techniques are the accuracy compared with creatinine clearance; in addition, these techniques do not require blood or urine samples and measure both global and differential renal functions. We calculated the GFR in this study using a computer analysis of scintigraphic images of the kidneys after a single intravenous injection of 99mTc DTPA.

Among studies evaluating the safety and complications of multiple access tracts during PCNL, the report by Singla and associates[2] describes a retrospective evaluation of 149 patients undergoing PCNL with multiple tracts for complex and staghorn renal stones. The complications included bleeding necessitating blood transfusion in 46 (30.8%) patients and other complications (pseudoaneurysms, sepsis, hydrothorax, and pneumothorax) in 21 others. Complete stone clearance was possible after a single session PCNL in 70.7% of cases. The authors concluded that an aggressive approach with multiple tracts in patients with staghorn calculi was effective and with acceptable morbidity. A similar conclusion was reached by Aron and colleagues[3] who performed 397 tracts in 121 renal units of patients with staghorn stones with an 84% clearance rate and acceptable complications.

In another report by Hegarty and Desai,[4] the authors compared the morbidity of PCNL using multiple tracts with that of single tract procedures. While both groups had comparable rates of complications (10%) and comparable mean drop in hemoglobin concentration, patients in the multiple

Table 3. Effect of Hypertension on Serum Creatinine and Glomerular Filtration Rate

	Normotensive patients (n = *75*)		*Hypertensive patients* (n = *27*)	
	Preoperative	*12 months postoperative*	*Preoperative*	*12 months postoperative*
Mean serum creatinine (±SD) mg/dL	1.57 (±0.74)	1.66 (±0.89)	1.90 (±0.52)	2.25 (±0.76)
Mean GFR (±SD) mL/min	49.9 (±13)	45.3 (±14.1)	44.9 (±11.8)	37.4 (±12.3)

SD = standard deviation; GFR = glomerular filtration rate.

Table 4. Patients' Distribution According to Chronic Kidney Disease Stage*

	Preoperative distribution	*Number of down-staged patients*	*Number of up-staged patients*	*Postoperative distribution at 1 year*
No. CKD/CKD stage 1	26	0	3	31
CKD stage 2	22	8	1	19
CKD stage 3	32	3	13	16
CKD stage 4	22	0	1	35
CKD stage 5	0	0	0	1

*Stage based on estimated glomerular filtration rate calculated by the abbreviated Modification of Diet in Renal Disease equation.
CKD = chronic kidney disease.

tracts group were more likely to receive blood transfusion (4 of 20 patients). In their study evaluating multitract PCNL, Cho and colleagues[5] compared 30 patients with multiple tracts with 79 patients with single-tract PCNL and found no significant differences in terms of stone clearance, transfusion rate, drop in hemoglobin, and hospitalization time.

Akman and associates[6] compared the morbidity of multiple tracts *vs* single-tract PCNL in 413 patients and found that bleeding was the most important complication, being more common in the multiple tracts group. The report by Muslumanoglu and colleagues[7] also described a higher rate of complications with multiple access tracts, especially when using a supracostal access. Our complication rate was consistent with the above mentioned studies with intraoperative bleeding occurring in 25 (24.5%) of our patients. This relatively high incidence after multiple tract PCNL might be attributed to large stone burdens in a large percentage of patients, possible platelet dysfunction in patients with renal impairment, initial low hemoglobin for many patients with a higher tendency of anesthetists to give transfusions to those patients with initially low hemoglobin.

In an attempt to decrease the complications from multiple accesses, some authors performed smaller-sized access tracts (mini-perc) however they failed to demonstrate a significant advantage in terms of reduced complication rates.[8,9]

The impact of multiple access tracts during PCNL on renal function is less clearly characterized in the literature. The immediate impact of single *vs* multiple tracts on renal function was evaluated in an animal model by Handa and coworkers[10] who measured GFR and renal plasma flow in pigs before and up to 4.5 hours after single- and multiple-tract percutaneous access procedures, and found a similar decline of about 60% of GFR in both groups. The same authors then retrospectively analyzed the acute renal hemodynamic response in 33 patients undergoing single (23 patients) or multiple (10 patients) tract PCNL and demonstrated similar and significant increases in serum creatinine on postoperative day 1 (0.33 ± 0.09 [standard error of the mean] mg/dL and 0.39 ± 0.11 mg/dL, respectively) and day 2 (0.33 ± 0.09 mg/dL and 0.25 ± 0.09 mg/dL, respectively), irrespective of the number of access tracts.[10]

Other studies assessed the effects of multiple tracts PCNL on renal function. In the report by Akman and associates,[6] the mean preoperative and postoperative creatinine concentrations were 1.03 mg/dL and 1.08 mg/dL in group 1 (single access), and 0.9 mg/dl and 1.03 mg/dl in group 2 (multiple accesses). Between the groups, the mean changes in creatinine were not statistically significant. Cho and colleagues[5] observed no significant differences in serum creatinine changes when the single-tract procedures were compared with the multiple tracts; these studies were retrospective and included essentially patients with normal overall renal function. In our prospective cohort, group A patients with normal preoperative serum creatinine values had a fairly stable serum creatinine level up to 12 months after the PCNL with the multiple tracts procedure, which is consistent with the above mentioned reports. The fact that the GFR of the involved renal unit estimated by renography at 12 months decreased significantly compared with preoperative values may denote a small deleterious effect of the procedure on the renal unit that was masked (when measuring serum creatinine) by the normal function of the contralateral kidney.

The impact of multiple tract procedures on renal function appears to be very different in patients with preexisting renal impairment. Hegarty and Desai[4] compared a small series of 20 patients undergoing PCNL through multiple tracts with a contemporary cohort of single-tract procedures, and found a significant rise in serum creatinine and a decrease in estimated creatinine clearance in the multiple tracts group. The deterioration in renal function was more pronounced in patients with existing renal insufficiency. Ozden and coworkers[11] reported on long-term outcomes of PCNL in a group of 67 patients with CKD, looking at possible risk factors for deterioration of renal function. Thirteen (18.8%) of 69 PCNL procedures necessitated multiple access tracts. The authors found that the number of tracts was a significant factor for renal function deterioration on univariate analysis but did not reach significance on multivariate analysis. Other important predictors of renal function deterioration included diabetes mellitus and urinary infection.[11] The modest sample size in this report may be a reason behind the lack of significance on multivariate analysis.

In our group of patients with baseline renal impairment, deterioration of renal function as evidenced by increases in serum creatinine level and decreases in GFR were significant and persistent throughout the 12-month follow-up. A subgroup of patients (10 of 52) experienced a clinically important drop of >25% in baseline GFR of the affected kidney. This significant decline was associated on multivariate analysis with preexisting renal impairment, diabetes, and hypertension. Looking at the data from another angle, we classified our cohort of patients into the CKD stages based on preoperative renal function; then we analyzed the changes at 1 year. We noted that some patients (mostly in CKD stage 2 with mildly reduced renal function) had an improvement in their CKD staging (reclassified to No CKD/CKD stage 1), but the most striking changes were seen in CKD stage 3 patients

(with moderately reduced renal function) of whom 40.6% had a deterioration of renal function large enough to move them to CKD stage 4. The authors believe that these findings should alert urologists to potential adverse impact on renal function when multiple-tract PCNL procedures are offered to hypertensive or diabetic patients or patients with impaired kidney function.

Conclusions

PCNL with multiple access tracts can adversely affect the function of the involved renal unit. Patients with preoperative baseline renal impairment, diabetes, or hypertension are particularly susceptible to renal function deterioration after the procedure, and this deterioration is only measurable using serum creatinine when a normal contralateral kidney is not present to compensate. The authors believe that these findings should alert urologists to potential adverse impact on renal function when multiple-tract PCNL procedures are offered to hypertensive or diabetic patients or patients with impaired kidney function. Alternatives to multiple-tract PCNL (flexible or combined retrograde/antegrade approaches) may be preferable in these patients.

Disclosure Statement

No competing financial interests exist.

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Address correspondence to:
Mohamed G. Elsheikh, MD
Department of Urology
Cairo University
Kasralaini Street
Cairo 1234
Egypt

E-mail: mohamed.galalelsheikh@gmail.com

Abbreviations Used

CKD = chronic kidney disease
CT = computed tomography
DTPA = diethylenetriaminepentaacetic acid
GFR = glomerular filteration rate
KUB = kidneys, ureters, and bladder
PCNL = percutaneous nephrolithotomy
SD = standard deviation
SWL = shockwave lithotripsy