Percutaneous nephrolithotomy: critical analysis of unfavorable results

Abdulkader Alobaidy, MD, Abdulla Al-Naimi, MD, Khalid Assadiq, MD, Haidar Alkhafaji, MD, Abdulla Al-Ansari, MD, Ahmed A. Shokeir, MD
Department of Urology, Hamad General Hospital, Doha, Qatar

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Objective: *To identify the risk factors of unfavorable results of percutaneous nephrolithotomy (PCNL).*
Patients and methods: *A total of 602 patients were subjected to 616 PCNL procedures. Patients were divided into two groups according to the results of treatment. Group 1 with favorable results includes patients who became stone free after a single PCNL procedure without major complications. Group 2 with unfavorable results includes three subgroups: a) Patients who developed major complications, b) Those who required second major intervention to complete stone removal, and c) Patients with residual stones > 4 mm at 3 month. Risk factors for unfavorable outcome were studied by univariate and multivariate analyses.*
Results: *Unfavorable results were documented in 176 patients (28.6%) due to major complications in 40 (6.5%), need for second intervention in 124 (20%), and presence of residual stones > 4 mm at 3 month in 12 (1.9%). The remaining 440 patients (71.4%) were considered of favorable outcome. Independent risk factors of unfavorable results on multivariate analysis were staghorn stones, multiple stones and stone largest diameter > 50 mm.*
Conclusion: *To optimize the results of PCNL, urologists should consider careful patient selection. Patients with staghorn stones, multiple stones or large stone burden are more susceptible to unfavorable outcome.*

Key Words: percutaneous nephrolithotomy, stone, kidney, risk factors

Introduction

Percutaneous nephrolithotomy (PCNL) is an effective, minimally invasive procedure typically used for the treatment of large or complex renal calculi.[1] The goal of PCNL is complete removal of the entire stone burden in as few procedures and with the least morbidity.[1]

PCNL is generally a safe treatment option and associated with low but specific complications.[2] Many complications are developing from the initial puncture with injury of surrounding organs. Other specific complications include postoperative bleeding and fever.[2]

To avoid the complications associated with PCNL and to ensure optimum outcomes for patients, urologists must consider the risk factors when planning or performing PCNL.[3] Only a few studies have investigated these risk factors[3-5] and one of these studies failed to identify any risk factors.[5]

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Address correspondence to Dr. Ahmed A. Shokeir, Urology & Nephrology Center, Mansoura, Egypt

Herein, we present a retrospective analysis of 616 procedures of PCNL aiming at identification of the risk factors of unfavorable results. Considering these risk factors by urologists will ensure optimum outcomes for patients.

Patients and methods

Patients

The data of 602 patients who were subjected to PCNL at our institution and completed follow up for at least 3 months were retrospectively analyzed. Of the patients, 14 underwent bilateral PCNL in two separate sessions; therefore, the analysis includes 616 PCNL procedures. Patients who had incomplete data were excluded from the analysis. Table 1 lists presentations indicating PCNL.

Preoperative patient evaluation included history, clinical examination, laboratory profiles and imaging studies. Laboratory tests performed were urine analysis and culture, serum creatinine, complete blood count, coagulation profile and liver function tests. Radiological investigations were plain abdominal x-ray (KUB), renal ultrasonography (US), excretory urography (IVP), or

TABLE 1. **Presentation indicating PCNL in 616 procedures**

	# patients	%
Incidental discovery	62	10
Pain	474	77
UTI	31	5
Renal impairment	37	6
Failed ESWL	63	10

A patient may have more than one presentation

noncontrast computerized tomography (NCCT) in patients with high serum creatinine (> 1.6 mg/dL).

Operative technique

With the patient prone, the skin was punctured at the posterior axillary line. Percutaneous renal access was established in the radiology department under biplane or multidirectional C-arm fluoroscopic guidance together with renal ultrasonography. The pelvicaliceal system was entered at the lower posterior calix in patients with renal pelvis or lower caliceal stone. Middle or upper calix punctures were used when stones were present in these calices. The tract was dilated using nephrostomy balloon (NephroMax, Boston Scientific Corporation, USA) which fits tightly to the 30 Fr Amplatz sheeth. Small stones were removed with forceps and large ones were disintegrated with pneumatic or ultrasonic lithotriptes. A 22 Fr nephrostomy tube was placed at the end of the procedure. The tube was removed after 1-2 days and the patient was sent home, provided absence of complications or residual stone.

Postoperative evaluation

KUB and tomography were performed for radiopaque stones, while NCCT was done for lucent stones. Postoperative course was reported and the stone-free rate was evaluated at hospital discharge or after 3 months in patients with residual stones.

Definition of study groups

Patients were divided into two groups according to the results of the treatment. Group 1 with favorable results includes patients who became stone free after a single PCNL procedure without any intraoperative or postoperative major complications. Group 2 with unfavorable results includes three subgroups: a) patients who developed major intraoperative or postoperative complications. We defined major complications in terms of severe bleeding (necessitating stoppage of the procedure, blood transfusion, angioembolization or surgical exploration), abdominal organ injury (colon, liver or spleen), pleural injury with significant hydro or hemo thorax necessitating fixation of chest tube and septicemia. b) Patients with significant residual stones requiring second major intervention including repeat PCNL with creation of new one or more punctures, ureteroscopy (URS) or extracorporeal shock wave lithotripsy (SWL). Doing a second look flexible nephroscopy through the same tract was not considered an unfavorable outcome. c) Patients discharged with residual stones > 4 mm which did not pass spontaneously after 3 months.

Statistical analysis

The two groups were compared using univariate (chi square and t-test) and multivariate (logistic regression) statistical testes to identify risk factors for unfavorable results. Receiver Operator Characteristic (ROC) curve was used to identify the cutoff value of largest stone diameter which gives the best sensitivity and specificity. The SPSS software package version 11.0 (Statistical Package for Solid Science, Chicago, IL, USA) was used for statistical analysis with $p < 0.05$ considered significant.

Computerized data included the following: a) Patient characteristics were age, sex, body mass index (BMI), clinical presentation (asymptomatic versus symptomatic) and history of open or endoscopic renal surgery. b) Renal characteristics were side (right, left or bilateral), renal morphology (no hydropnephrosis or hydropnephrosis and congenital anomalies (yes or no). c) Stone characteristics were number (single, multiple, staghorn), largest diameter, location in the kidney (pelvis, caliceal or pelvicalceal). d) Operative variables were punctured calyx (lower, middle or upper) and skin puncture (subcostal or supracostal).

Results

The study was carried out in 602 patients, including 509 males and 93 females, with a mean age of 41.5 ± 11.1 years (range from 3-75). Of the patients, 13 were children below the age of 18 years. Patients underwent a total of 616 procedures, including right PCNL in 298, left PCNL in 290 and bilateral in 14. Mean stone largest diameter was 40 mm ± 16 mm (range 10 to 120).

Adjuvant procedures before stone extraction were carried out in 25 patients (4%), including URS to push–up a stone in lumbar ureter in 15 patients and optical urethrotomy in 10.

Table 2 depicts major intraoperative and postoperative complications and their methods of treatment. All complications were treated successfully with favorable outcome except one patient who experienced severe intractable hemorrhage not responding to

TABLE 2. **Definition of unfavorable outcome in 616 PCNL procedures**

	# procedures (%)	Treatment	
Bleeding	20 (3.2)	Blood transfusion	(13)
		Angioembolization	(5)
		Open surgery	(1)
		Nephrectomy	(1)
Septicemia	15 (2.4)	Intravenous antibiotics	(15)
Hydro/ hemothorax	4 (0.6)	Chest tube	(4)
Colonic injury	1 (0.2)	Conservative	(1)
Residual stone (> 4 mm)	136 (22)	Medical treatment	(12)
		SWL	(95)
		URS	(11)
		RE-PCNL	(18)

angioembolization. The patient was explored and attempts to control bleeding were unsuccessful, therefore, nephrectomy was done.

The overall stone free rate at discharge from the hospital was 75% after one session and 77% after a second session. None of the patients required more than two sessions of PCNL. The overall stone free rate at 3 month was 80%. Presence of residual stones > 4 mm at 3 month was considered unfavorable outcome.

Of the patients, 18 patients required repeat PCNL through a new puncture because of significant residual stones that could not be treated by SWL, 11 underwent URS for removal of migrated stones and 95 required SWL for treatment of residual stones. Performing a secondary procedure (re-PCNL, URS, SWL) was considered unfavorable outcome.

Of the 616 PCNL procedures, unfavorable results were documented in 176 patients (28.6%) due to major intraoperative or postoperative complications in 40 (6.5%), need for second intervention in 124 (20%), and presence of residual stones left for medical treatment and follow up in 12 (1.9%), Table 2. The remaining 440 patients (71.4%) were considered of favorable outcome.

Tables 3 and 4 show the categorical and continuous factors of unfavorable outcome after PCNL, respectively. Table 5 is a univariate regression analysis showing the odds ratio of the risk factors for unfavorable outcome. Significant risk factors on univariate analysis were staghorn stones, multiple stones, caliceal stone location and stone largest diameter. ROC curve showed that a cutoff value of 50 mm of stone largest diameter gives a sensitivity of 74% and a specificity of 85%. Factors

TABLE 3. **Univariate analysis of categorical risk factors of unfavorable outcome after 616 PCNL procedures in 602 patients**

Categorical factors	# unfavorable/ total # (%) (%)	p value chi-square
Sex (# patients)		
Male	150/509 (29.5)	0.26
Female	22/93 (23.7)	
Clinical presentation (# kidneys)		0.4
Incidental	15/62 (24.2)	
Symptomatic	160/554 (28.9)	
Side (# patients)		0.70
Right	83/298 (27.9)	
Left	81/290 (27.9)	
Bilateral	4/14 (28.6)	
Renal morphology (# kidneys)		0.27
# hydronephrosis	97/361 (26.9)	
Hydronephrosis	79/255 (31)	
Congenital anomalies (# kidneys)		0.57
Yes	3/8 (37.5)	
No	173/608 (28.5)	
Stone size (# kidneys)		0.001
< 50 mm	42/414 (10.1)	
≥ 50 mm	134/202 (66.3)	
Stone number (# kidneys)		0.001
Single	33/315 (10.5)	
Multiple	46/121 (38)	
Staghorn	97/180 (53.8)	
Recurrence (# kidneys)		0.25
No	107/360 (29.7)	
Yes	64/256 (25)	
Stone site (# kidneys)		0.001
Pelvic	30/219 (13.7)	
Caliceal	18/105 (17.1)	
Pelvicaliceal	128/292 (43.8)	
Punctured calix (# punctures)		0.78
Lower	125/449 (27.8)	
Middle	29/100 (29)	
Upper	27/82 (32.9)	
Skin puncture (# punctures)		0.56
Subcostal	165/566 (29)	
Supracostal	21/65 (32.3)	

TABLE 4. **Univariate analysis of continuous risk factors of unfavorable outcome after PCNL**

Continuous factors	Favorable	Unfavorable	p value t-test
Age, yrs, mean ± SD	41.9 ± 11.3	40.8 ± 10.4	0.27
BMI, mean ± SD	27.2 ± 6.2	26.1 ± 5.2	0.10
Stone largest diameter mm, mean ± SD	34.4 ± 13.5	54.2 ± 13.6	0.001

TABLE 5. **Univariate logistic regression analysis of risk factors for unfavorable outcome after 616 procedures of PCNL**

Variables	OR (95% CI)	p value
Stone size		
< 50 mm	1	
≥ 50 mm	17.5 (11.3-26.9)	0.001
Stone number		
Single	1	
Multiple	5.2 (3.1-8.8)	0.001
Staghorn	9.9 (6.3-15.9)	0.001
Stone site		
Pelvic	1	
Caliceal	1.3 (0.7-2.5)	0.41
Pelvicaliceal	4.9 (3.1-7.7)	0.001

which sustained significance on multivariate analysis were staghorn stones, multiple stones and largest stone diameter > 50 mm, Table 6.

Discussion

PCNL is an established method for treatment of large and complex renal calculi. Refinement of the technology and increasing experience in the last two decades led to increased safety and efficacy.[3] Considering the risk factors of unfavorable outcome will further improve the results of this common procedure.

In a recent study, El-Nahas et al identified five risk factors predicting severe bleeding due to PCNL in 3878 procedures.[3] The identified factors were upper caliceal puncture, solitary kidney, staghorn stone, multiple punctures and inexperienced surgeon. Three of these five factors were also identified in the present series. Our study has an advantage of considering other unfavorable results rather than severe bleeding such as organ injuries, necessity of additional interventions and leaving residual stones.

Blood loss is a normal feature of PCNL. It is considered a complication only when blood transfusion is required. The rate of significant bleeding in the present series is 3.2% which matches favorably to the previously reported rates with a range between 3% to 23%.[3-6] Fortunately, in the vast majority of cases bleeding can be controlled with conservative measures. The necessity of renal embolization to control severe bleeding is low (range 0.3% to 1.4%).[3-6] Embolization was necessary in 0.8%% in our series.

A common source for bleeding during PCNL is the nephrostomy tract itself due to lacerations induced during definitive surgery in terms of stone removal. This bleeding can be prevented if the kidney is strictly punctured through a calix and a minimal angulation of the nephroscope shaft is used. To avoid extensive angulations, a flexible nephroscope should be used for

TABLE 6. **Multivariate logistic regression of risk factors for unfavorable outcome after 616 PCNL procedures**

Independent factor	B	SE	EXP (B)	95%CI	p value
Multiple stones	1.71	0.455	5.53	2.3-13.5	< 0.001
Staghorn stone	1.25	0.508	3.48	1.3-9.4	< 0.01
Caliceal stones	0.54	0.374	1.72	0.8-3.6	0.15
Stone largest diameter > 50 mm	3.0	0.338	20.27	10.4-39.3	< 0.001

B = regression coefficient; SE = standard error; EXP (B) = relative risk; CI = confidence interval

stone parts in other calices. Fluoroscopic monitoring of the dilatation process can also minimize the risk of laceration [2].

The risk factors of colonic injury are horseshoe kidney, left-side puncture, thin old patient, inflamed colon and previous bowel surgery.[7] Presence of these risk factors may increase the incidence of colonic injury up to 1%. The rate of puncturing of the colon can be minimized by the use of sonographic control and correct patient selection. Computerized tomography is useful in high risk patients to identify the anatomical correlation between the colon and the targeted calix.

The risk of an injury of the pleura increases with supracostal punctures.[8,9] A supracostal puncture using ultrasound control or a puncture after exhalation may prevent pleural injury. The presence of lower calix access in combination with flexible nephroscopy practically avoids this complication.[10]

In our series, 15 patients (2.4%) developed sepsis and successfully treated. Sepsis rate reported in the literature vary from 0.97[11] to 4.7%.[12] In cases of septicemia, the patient should receive intensive therapy including forced diuresis, antibiotics, optimal renal drainage and electrolyte control.[2]

The importance of achieving a stone free state is underscored by the natural history of clinically insignificant residual fragments (CIRFs) following SWL, whereby several investigators have demonstrated that a substantial number of patients with CIRFs will experience a symptomatic episode or require additional intervention within 2 years of undergoing SWL.[13-15] In a recent study, Raman et al reviewed the natural history of residual fragments after PCNL in 728 patients. They concluded that the size and location of post-PCNL residual fragments correlate with stone related events defined as growth of a residual fragment, or need for emergency room visit, hospitalization or additional intervention attributable to the residual fragments.[1] Second look flexible nephroscopy may be of benefit in patients with residual fragments larger than 2 mm or in those with fragments located in the renal pelvis or ureter.

Some may argue that a secondary procedure could not be considered as an unfavorable outcome, particularly when a decision is taken to stage the PCNL or to provide sandwich SWL to improve overall results. Nevertheless, it is our policy and that of others[3] to render the patients stone free in a single session by the use of multiple punctures and flexible nephroscopy. To clear all the stones in a single session is one of the advantages of PCNL that saves the patients multiple interventions with several anesthetic sessions and psychological traumas. Moreover, multiple sessions may increase the morbidity and aggrevate both the direct and indirect costs through extension of the operative time, hospital stay and the periods of convalescence before return to daily activity and regular work.

Conclusion

To optimize the results of PCNL, urologists should consider careful patient selection. Patients with staghorn stones, multiple stones or large stone burden are more susceptible to unfavorable outcome. □

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EDITORIAL COMMENT

Re: Percutaneous nephrolithotomy: critical analysis of unfavorable results

The authors are to be commended for presenting and critically analyzing their technique for percutaneous nephrolithotomy, stratifying their outcomes as favorable and unfavorable. Unfavorable outcomes included patients who had residual stones on 3 month follow up, patients who had major intraoperative or postoperative complications, and patients who needed further procedures to clear their stones. Multivariate analysis showed that staghorn stones, multiple stones or large stone burdens are more susceptible to unfavorable outcomes.

Many urologists, including the authors, consider additional procedures as an unfavorable outcome although many patients need multiple procedures to definitively clear their stone burden. Additional procedures to clear complex stones should not be considered as an unfavorable outcome; whereas additional procedures for simple stones in uncomplicated patients or due to perioperative complications would clearly classify as unfavorable.

Moreover, the authors consider second look nephroscopy through the same tract more morbid than performing additional punctures in the same session. Multiple studies have shown that multiple tracts are associated with higher bleeding and transfusion rates. The authors did not include patients who had multiple tracts in the unfavorable group. Also, the authors did not evaluate the impact of having multiple tracts during percutaneous nephrolithotomy on the overall outcomes.

Certainly, the current study evaluates a large series of percutaneous stone surgery with realistic and honest outcomes recorded. This further emphasizes the need for multi-center studies to develop predictive models that can be used by urologists pre-operatively to help predict outcomes.

Khaled Shahrour, MD, FRCSC
Clinical Instructor of Urology

Timothy D. Averch, MD, FACS
Associate Professor, Director of Endourology

Department of Urology
University of Pittsburgh Medical Center
Pittsburgh, PA
USA