Factors Influencing Complications of Percutaneous Nephrolithotomy: A Single-Center Study

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Purpose: Percutaneous nephrolithotomy (PNL) is a minimally invasive procedure used for successful treatment of renal calculi. However, it is associated with various complications. We assessed the complications and their potential influencing factors in patients who had undergone PNL.

Materials and Methods: In total, 1750 patients who had undergone PNL from November 2003 to June 2011 were evaluated retrospectively. PNL complications and possible contributing risk factors (age, sex, serum creatinine level, previous operations, hydronephrosis, calculi size, localization, opacity, surgeon's experience, accessed calyxes, number of accesses, and costal entries) were determined. Receiver operating characteristic (ROC) analysis was used to investigate the cutoff values of the data. Ideal cutoff value was determined by Youden's J statistic. All the demographic and clinical variables were examined using backward stepwise logistical regression analysis. Continuous variables were categorized with logistic regression analysis according to the cutoff values.

Results: Complications occurred in 396 (24.4%) patients who had undergone PNL. Hemorrhage requiring blood transfusion occurred in 221 (12.6%) patients, hemorrhage requiring arterial embolization occurred in 7 (0.4%) patients, perirenal hematoma occurred in 17 (0.97%) patients, hemo-pneumothorax occurred in 32 (1.8%) patients, and colon perforation occurred in 4 (0.22%) patients. Three patients (0.06%) died of severe urosepsis, and one patient (0.02%) died of severe bleeding. The calculus size, localization, access site, number of accesses, presence of staghorn stones, surgeon's experience, and duration of the operation significantly affected the complication risk.

Conclusion: Our retrospective evaluation of this large patient series reveals that, PNL is a very effective treatment modality for kidney stones. However, although rare, serious complications including death can occur.

Keywords: nephrostomy; percutaneous; multivariate analysis; postoperative complications; etiology; retrospective studies; treatment outcome.

INTRODUCTION

Access to the collecting system of the kidneys was first reported in the 1950s, whereas access to the collecting system for the purpose of kidney stone treatment was first performed in the 1970s and 1980s.[1-3] Nowadays percutaneous nephrolithotomy (PNL) is gold standard treatment modality for upper urinary tract stones.[4] PNL has a success rate of over 95% depending on the kidney anatomy, stone size, stone localization, patient-specific anatomical factors, and surgeon's experience; however, it is associated with some complications; including death.[5] In this study, we retrospectively analyzed the complication rates and the factors that might affect these complications in a large number of patients treated by PNL.

MATERIALS AND METHODS

Study Population

The data of patients who underwent PNL by a single surgeon were examined retrospectively. Detailed physical examinations, blood biochemistry assays, urinalysis, and urine culture were performed preoperatively in all the patients. They also underwent preoperative direct urinary tract radiography, urinary ultrasonography, and intravenous urography, and unenhanced spiral computed tomography, if necessary. Calculated stone surface area (CSA) was evaluated by multiplying the maximum diameter, width, ¼ π of the stone seen on the plain radiography.

Appropriate antibiotic therapy was administered to those patients with growth on their preoperative urine cultures. Patients without sterile urinary cultures despite appropriate antibiotic therapy, underwent PNL under antibiotic administration.

Surgical Procedure

A 6 to 7 French (F) ureteral catheter was inserted under C-arm fluoroscopy. The patients were placed in the prone position, and the collecting system of the kidney was accessed with needle puncture under fluoroscopy guidance. After Amplatz dilation, 30 F sheath was positioned and only in a small number of children 20 F sheath was used. Stone fragmentation was then performed with pneumatic lithotripter. Clearance of the stone fragments was assessed with fluoroscopy. At the end of the procedures, a re-entry nephrostomy catheter

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was placed, and antegrade pyelography was performed to check for extravasation and colonic injury. Stone clearance was assessed on a direct urinary tract X-ray.

Post-Operative Evaluations

Patients with no opacities on the X-ray were considered stone free, those with opacities of under 4 mm were considered to have clinically insignificant residual fragments (CIRF) and those with opacities of over 4 mm was defined as failure. Nephrostomies were withdrawn after recovery of hematuria. Fever was considered to be present in patients with a body temperature over 38°C during the postoperative period. Cold compression, antipyretics, and antibiotic treatment were administered as necessary. A ureteral double J stent was placed if urine leakage from the nephrostomy tract continued for 72 to 96 hours. Anteroposterior chest radiography was performed to evaluate possible pleural injury in patients in whom supracostal and upper pole access was performed. Patients with mild effusion on chest radiographs were followed up, and those with severe effusion were treated by insertion of a chest tube. PNL-associated complications such as hemorrhage requiring transfusion, fever, prolonged urinary drainage, severe urosepsis, pleural injury, colon injury, and hemorrhage requiring arterial embolization, perirenal hematoma, and death were classified according to Modified Clavien Classification.

The patient-related factors including age, sex, serum creatinine level, previous operations, presence of hydronephrosis, kidney stone size and opacity, presence of a solitary kidney, horseshoe kidney, staghorn stones and urinary tract infection and the procedure-related factors including the surgeon's experience, caliceal accesses, number of accesses, duration of the operation, and supracostal punctures that might influence the development of PNL associated complications were analyzed.

Patients were classified according to the presence of hydronephrosis on radiologic assessment. The degree of hydronephrosis was not evaluated as a separate factor. The stones were divided according to location as simple (pelvis, isolated calyx) or complex (multiple calices, staghorn). The presence of a staghorn stone was re-evaluated as a separate factor apart from the stone size. The accessed calyx was evaluated as either isolated or multiple, and the number of accesses were evaluated as either single or multiple. The cutoff values of the stone size, the surgeon's experience (assessed according to the number of patients surgically treated) and the duration of the operation (the time from initial calyx access to the placement of the nephrostomy catheter) for the development of complications was evaluated.

Statistical Analysis

Receiver operating characteristic (ROC) analysis was used to investigate the cutoff values of the data. Ideal cutoff value was determined by Youden's J statistic. All the demographic and clinical variables were examined using backward stepwise logistical regression analysis as to be a risk factor or not. Continuous variables which had significant cutoff values, was categorized with logistic regression analysis according to the cutoff values. Values of $P < .05$ were considered to be statistically significant. The data were entered into an Exceltm (Microsoft, Redmond, WA, USA) database and analyzed with Statistical Package for the Social Science (SPSS Inc, Chicago, Illinois, USA) version 20.0.

Table 1. Clinical characteristics of the study patients and features of operations.

Variables	Values
Mean age, years (range)	45.82 (3-81)
Gender, no (%)	
Male	1055 (60.3)
Female	695 (39.7)
Stone site, no (%)	
Left	857 (51)
Right	893 (49)
Solitary, no (%)	36 (2.05)
Previous operation, no (%)	
Yes	329 (18.8)
No	1421 (81.8)
Mean serum creatinine (mg/dL)	1.03
Mean stone size, cm^2 (range)	7.5 (0.25-95)
Presence of hydronephrosis, no (%)	
Yes	1220 (69.7)
No	530 (30.3)
Stone opacity, no (%)	
Semi/Non opaque	35 (2)
Radiopaque	1715 (98)
Mean operation time, min (range)	56.79 (15-330)
Access number, mean (range)	1.40 (1-7)
Single	1298 (74.2)
Multiple	452 (25.8)
Calyx entry, no (%)	
Supracostal	93 (5.3)
Subcostal	1657 (94.7)
Mean duration with nephrostomy, days (range)	2.49 (1-12)
Mean hospitalization, days (range)	3.08 (1-25)

RESULTS

A total of 1750 patients underwent PNL from November 2003 to June 2011. The patient and operation data are shown in **Table 1**. Stone free status was obtained in 1485 (84.8%) of the 1750 patients, CIRF were evident in 217 (12.4%), and failure occurred in 48 (2.7%). Complications occurred in 396 (24.4%) patients and related data are summarized according to the modified Clavien classification in **Table 2**. The complications were compared with those reported in the literature (**Table 3**). Urosepsis developed in three (0.17%) patients during the postoperative period, and one patient (0.05%) developed severe bleeding; all four of these patients died. The factors that might affect the complication rates are shown in **Tables 4 and 5** according to categorized and continuous variables, respectively. The cutoff value of stone size for the development of complications was 710 mm2 (sensitivity 41.7%; specificity 69.4%), the

Table 2. Complication rates according to Modified Clavien Classification.

Modified Clavien Classification	Values
Grade 1 (Fever)	80 (4.5)
Grade 2 (Blood transfusion)	221 (12.6)
Grade 3a (Extravasation)	28 (1.6)
Grade 3b	
Perirenal hematoma	7 (0.4)
Arteriovenous fistula	17 (0.97)
Grade 4a	
Colon injury	4 (0.22)
Pleural injury	32 (1.82)
Grade 4b (Sepsis)	3 (0.17)
Grade 5 (Death)	4 (0.22)

Data are presented as no. (%).

cutoff value of operation time was 67 minutes (sensitivity 41.4%; specificity 79.2%) and the cutoff value of the cases for convenient skills to decrease complication rates was 565 (sensitivity 72.3%; specificity 48%). Although supracostal access did not increase the risk for general complications, it was a risk factor for pleural injury. Pleural injury was observed in 15 of 95 patients who underwent supracostal access (16.1%), whereas it occurred in 17 of 1657 patients (1.1%) who underwent subcostal access ($P < .001$). While the presence of staghorn stone, multiple-caliceal accesses, large stone size and the longer duration of operation significantly increased the risk of the most common complication (blood transfusion), the presence of a horseshoe kidney and greater surgical experience were associated with a significantly decreased rate of blood transfusion (**Tables 6 and 7**).

DISCUSSION

PNL is considered to be the standard treatment for staghorn renal calculi, large volume renal calculi, upper tract calculi refractory to other treatment modalities, difficult lower pole stones, cysteine nephrolithiasis, and calculi in anatomically abnormal kidneys.[6] PNL is typically a very safe and well-tolerated procedure, but it is associated with a specific set of complications.[7,8]

Michel and colleagues evaluated more than 100 patients and found that the most common complications of PNL were extravasation (7.2%) (Grade 3a), blood transfusion (11.2%-17.5%) (Grade 2), and fever (21.0%-32.1%) (Grade 1).[5] The rarer complications in their study were septicemia (0.3%-4.7%) (Grade 4b), colon injury (0.2%-4.8%) (Grade 4a), and pleural injury (0.3%-1.0%) (Grade 4a). The complications seen in our study are summarized in **Table 2** according to the modified Clavien system. Fever was the most common Grade 1 complication which was treated with cold compression and antipyretics. The most common Grade 3a complication was urinary leakage that exceeded 72 hours in 28 (1.6%) patients. A double J ureteral catheter was placed in these patients. The Grade 3b complications included perirenal hematoma and arteriovenous fistula. Arterial embolization was performed in the patients with arteriovenous fistulas, and conservative treatment or placement of a double J ureteral catheter was performed in the patients with perirenal hematomas.

The most common Grade 4a complications were pleural injury and colon injury. A chest tube was placed in 18 of the patients with pleural injury; the remaining 14 were treated with conservative management. One of the patients with colon injury underwent an operation by a general surgeon perioperatively, and three underwent repair procedures postoperatively. Sepsis developed in three patients (Grade 4b), and these patients died despite intense antibiotic and supportive treatment. These findings are consistent with those in the literature.[6,8-10]

Hemorrhage is an important morbidity associated with PNL. Kessaris and colleagues reported a 0.8% rate of hemorrhage requiring embolization following PNL.[10] In another large series, the incidence of serious arterial bleeding after PNL was reportedly 0.5% to 1.0%.[11] Additionally, Mousavi-Bahar and colleagues reported a 0.6% transfusion rate among 671 patients, while El-Nahas and colleagues reported a 16.0% transfusion rate among 241 patients.[12,13] In our study, hemorrhage requiring transfusion occurred in 221 (12.6%) patients, while hemorrhage requiring arterial embolization occurred in 7 (0.4%).

Sampaio reported a 67% vessel injury rate and a 17% arterial (interlobar) injury rate in percutaneous inter-

Table 3. Comparison of our complications in percutaneous nephrolithotomy with the literature.

Complications	Mousavi-Bahar[12] (n = 671)	Rosetta[6] (n = 5803)	Lee[9] (n = 582)	Our Experience (n = 1750)
Transfusion	0.6	5.7	11.2	12.6
Hemorrhage requiring intervention	0.15	NA	1.2	0.4
Fever	NA	10.5	22.4	4.5
Sepsis	0	NA	0.8	0.17
Colon injury	NA	NA	0.2	0.22
Pleural injury	0.7	1.8	3.1	1.82
Extravasation/Urine leakage	5.2	3.4	7.2	1.6
Death	0.3	0.3	0.3	0.22

Abbreviation: NA, not available.
Data are presented as %.

Table 4. The factors that might affect the complication rates (categorized variables).

Factors	Patients, no	Complications, no (%)	*P* Value
Gender			
Male	1055	198 (18.8)	_____
Female	695	198 (28.5)	
Localization			
Simple	772	149 (19.3)	_____
Complex	978	247 (25.3)	
Access site			
Lower calyx	619	133 (21.5)	< .001
Middle calyx	592	113 (19.1)	
Upper calyx	172	33 (19.2)	
Multiple calices	367	117 (31.9)	
Number of accesses			
Single Access	1298	251 (19.3)	< .001
Multiple Accesses	452	145 (32.1)	
Costal entry			
Subcostal	1657	374 (22.6)	_____
Supracostal	93	22 (23.7)	
Staghorn stone			
Yes	164	59 (36)	< .001
No	1586	337 (21.2)	
Solitary kidney			
Yes	36	12 (33.3)	_____
No	1714	384 (22.4)	
Horseshoe kidney			
Yes	39	5 (12.8)	_____
No	1711	391 (22.8)	
Opacity			
Semi/non opaque	35	6 (17.1)	_____
Radiopaque	1715	390 (22.7)	
Previous operation			
Yes	329	72 (21.9)	_____
No	1421	324 (22.8)	
Hydronephrosis			
Yes	1220	262 (21.5)	_____
No	530	134 (25.3)	
Preoperative infection			
Yes	165	45 (27.3)	_____
No	1585	351 (22.1)	

ventions performed on upper calices.[14] Considering this anatomic feature of the kidney, lower-calyx access is considered to be safest with respect to complications. However, Kukreja and colleagues showed that the location of the calyx did not affect the development of complications.[15] Although this is a controversial finding, the complication rates associated with upper calyx access in our study were lower than those associated with lower calyx access, although not statistically significant (19.2% vs. 21.5%, respectively) (**Table 4**). Upper calyx

Table 5. The factors that might affect the complication rates (continuous variables).

Variables	Values	
Age	Cutoff value	_____
	AUC (SE)	0.478 (0.017)
	P value	.188
Duration of operation (min)	Cutoff value	67
	AUC (SE)	0.637 (0.016)
	P value	< .001
Surgeon's experience (no.)	Cutoff value	565
	AUC (SE)	0.383 (0.017)
	P value	< .001
Stone size (cm^2)	Cutoff value	7.10
	AUC (SE)	0.560 (0.016)
	P value	< .001

Abbreviations: AUC, area under the curve; SE, standard error.

access increases the risk of pleural injury; however, establishing access from this site may be easier than lower and middle calyx access, because the guide can be more easily placed in the ureter when it is inserted from the upper calyx. Amplatz dilatation performed through a guide in the ureter can be more easily and rapidly accomplished. Moreover, manipulations related the renal pelvis and other calices can be performed more comfortably with upper-pole than with lower-pole access. Placement of a guide in the renal pelvis and ureter is sometimes difficult with lower calyx access; this can result in problems, particularly bleeding during dilatation. In the present series, most blood transfusions occurred in association with access of multiple calyxes, followed by lower calyx access (22.1% and 12.6%, respectively) (**Table 5**). This rate was 8.3% in the middle-calyx group, and lowest requirement for blood transfusion occurred in association with isolated upper calyx access. The blood transfusion rates in patients with isolated lower calyx access were significantly higher than those in patients with isolated middle and isolated upper calyx access ($P = .014$ and $P = .009$, respectively). No significant difference in the rate of blood transfusion was found between middle and upper calyx access ($P = .884$). Lower calyx access is generally recommended in the literature. According to our own experience, however, upper calyx access seems to be more convenient and is associated with lower hemorrhage rates. Therefore, we do not believe that the surgeon should be insisted on lower calyx access; if the middle and upper calyxes seem to facilitate stone removal, it would be wise to utilize access through these calyxes.

Table 6: Factors affecting blood transfusion (categorized variables).

Factors	Patients (no.)	Blood Transfusion no. (%)	*P* Value
Access site			
Lower calyx	619	78 (12.6)	< .001
Middle calyx	592	49 (8.3)	
Upper calyx	172	13 (7.6)	
Multiple calices	367	81 (22.1)	
Number of access			
Single	1298	127 (9.8)	< .001
Multiple	452	94 (20.8)	
Staghorn stone			
Yes	164	41 (25.0)	< .001
No	1586	180 (11.3)	
Horseshoe kidney			
Yes	39	0 (0)	-
No	1711	221 (12.9)	

Table 7. Factors affecting blood transfusion (continuous variables).

Age	Cutoff Value	Values
	AUC (SE)	0.496 (0.021)
	P value	.858
Duration of operation (min)	Cutoff value	67
	AUC (SE)	0.679 (0.020)
	P value	< .001
Surgeons experience (no.)	Cutoff value	647
	AUC (SE)	0.361 (0.021)
	P value	< .001
Stone size (cm^2)	Cutoff value	5.93
	AUC (SE)	0.588 (0.022)
	P value	< .001

Abbreviations: AUC, area under the curve; SE, standard error.

PNL is associated with lower success rates and higher risks of complications in the treatment of staghorn and complex stones than in the treatment of simple stones. Generally, more than one working channel is needed to clear these stones. Stoller and colleagues found that the formation of multiple working channels increased the hemorrhage rate.[16] According to the kidney stone guidelines of the American Urological Association (AUA), the complication rate associated with staghorn stones is 7% to 27%, and the transfusion rate is about 18%.[7] The presence of staghorn kidney stones and the formation of multiple working channels are independent factors associated with the development of hemorrhage.[16,17] In a retrospective study of factors affecting hemorrhage in 193 patients who underwent PNL, multiple accesses increased bleeding.[18] Additionally, Akman and colleagues reported that the bleeding rates were higher in association with multiple calyx than isolated calyx access.[19]

In a study of 619 individuals, Akman and colleagues found that stone size was an enhancing factor for transfusion rates.[19] In the present study, we found that a larger stone was an enhancing factor for both complications and blood transfusions (P = < .001 and P = .001, respectively; cutoff value, 593 mm^2). In a study of the vascular structure of horseshoe kidneys, Jenetschek and Kunzel reported that a significant portion of the blood flow in the kidneys occurs on the medial surface; therefore, posterior access would cause fewer vascular injuries in horseshoe kidneys.[20] The present study supports this finding. The transfusion rate in our series was 12.6% in general, and no blood transfusion was needed following PNL in 39 patients with horseshoe kidneys. Similarly Darabi and colleagues and Ghoneimy and colleagues reported no blood transfusion in their series of PNL in horseshoe kidney.[21,22]

A prolonged operation time is another factor that enhances the rates of complications and blood transfusions according to the general literature. Akman and colleagues reported that the cutoff operation time for blood transfusion was 58 minutes; operation times exceeding this value increased the need for blood transfusions 2.82-fold.[19] In the present study, the cutoff time was found to be 67 minutes, and the complication frequency increased in patients who underwent operations exceeding this duration. The surgeon's experience is also a potential factor influencing the complications and the hemorrhage risk. Previous studies have shown that there is a negative correlation between surgical experience and bleeding risk.[17] Allen and colleagues suggested that 60 PNL cases are needed for surgical adequacy, while 115 are needed for surgical excellence.[23] In the present study, the blood transfusion rate was 31.0% for the first 100 cases and 9.2% for the 500th to 1750th case. The cutoff surgeon experience was found to be 565 cases for decreasing complications and 647 cases for decreasing blood transfusion rates. The possible explanation for the high cutoff values of surgical experience in our study was considered to be the effect of increasing the number of difficult and complex cases as surgeon experience increases.

CONCLUSIONS

Although PNL is generally a safe treatment modality for kidney stones, the surgeon must remember that serious complications such as death may occur. The complication rates in the present study were consistent with those in the general literature. Larger stones, complex stone, multiple-calyx access, an increased number of accesses, presence of staghorn stones, lower surgical experience, and prolonged operation times increased the complication rates.

CONFLICT OF INTEREST

None declared.

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