ORIGINAL RESEARCH
Endourology
Doi: 10.4274/jus.galenos.2023.2022.0068
J Urol Surg, 2023;10(3):245-252

Evaluation of Factors Affecting Success Rate in Percutaneous Nephrolithotomy: A Five-Year Experience

Sevgin Yılmaz[1], Murat Topcuoğlu[2], Fuat Demirel[1]

[1]University of Health Sciences Turkiye, Dışkapı Yıldırım Beyazıt Training and Research Hospital, Clinic of Urology, Ankara, Turkiye
[2]Alanya Alaaddin Keykubat University Faculty of Medicine, Department of Urology, Alanya, Turkiye

Abstract

Objective: To analyze the parameters that are believed to impact the success rate in patients undergoing percutaneous nephrolithotomy and to determine the factors that have a significant effect.

Materials and Methods: Success rates of 508 patients who underwent percutaneous nephrolithotomy were determined over a five-year period. Evaluation was performed with the medical history, non-contrast computerized tomography, and clinical research form in the first, third, and sixth months postoperatively. Patient characteristics, stone characteristics, and operation details were analyzed, and their effects on success were investigated. In the evaluation of the success rate, the results of the first month, were considered.

Results: No significant difference was shown between the successful and unsuccessful groups in terms of demographic features. Morbidities such as body mass index, hypertension, diabetes mellitus, hyperlipidemia, and heart disease had no effect on success. Solitary kidney or congenital renal anomaly, degree of hydronephrosis, and high preoperative serum urea creatinine levels did not have a significant impact on the success rate. Significant effects of parameters such as stone volume greater than 15 cm^2, complex stones, infection and cystine stones, intraoperative complication rate, and operation time on success were investigated ($p<0.001$, $p=0.038$, $p=0.014$, $p=0.010$, $p=0.022$, $p=0.030$, respectively). Success rates decreased statistically in cases with accompanying macroscopic hematuria ($p=0.032$). Previous surgery, extracorporeal shock wave lithotripsy history, and multifocal access had no effect however surgical experience increased the success rate ($p=0.036$).

Conclusion: The success rates in percutaneous nephrolithotomy can be enhanced by examining the factors that may have an impact and taking necessary precautions relevant to these factors.

Keywords: Percutan nephrolithotomy, success rate, predictive

Introduction

The goal of treatment selection in renal stones is to achieve the highest success rate with minimal complications and morbidity. Treatment options for kidney stones include extracorporeal shock wave lithotripsy (ESWL), ureterorenoscopy, percutaneous nephrolithotomy (PNL), and open or laparoscopic surgery. The main parameter in the selection of renal stone treatment is the stone size. In European and American urology guidelines, PNL is recommended as the first choice for the removal of kidney stones larger than 2 cm (1). PNL is almost completely replaced by open surgery for treating kidney stones bigger than 2 cm due to its advantages of being minimally invasive, cost-effective, short operative time, short hospital stay, lower complication rate, and high success rate. Although PNL is more invasive than other minimally invasive methods currently available, the trend in kidney stone surgery with advanced, more sophisticated equipment thanks to advancing technology is to use PNL more and more. In a recent meta-analysis by Chung et al. (2), the highest success and stone-free rate was achieved with PNL in kidney stones larger than 2 cm compared to other treatment modalities. Failure can lead to complications, increased additional treatment, and economic burden for the patients and the health system. Therefore, reliable prognostic parameters are needed to optimize the choice of treatment in patients, to plan the operation, to provide information about the operation and

Correspondence: Sevgin Yılmaz MD, University of Health Sciences Turkiye, Dışkapı Yıldırım Beyazıt Training and Research Hospital, Clinic of Urology, Ankara, Turkiye
Phone: +90 505 265 30 57 **E-mail:** sevginyilmaz80@gmail.com **ORCID-ID:** orcid.org/0000-0001-8300-4119
Received: 02.08.2022 **Accepted:** 21.01.2023

Cite this article as: Yılmaz S, Topcuoğlu M, Demirel F. Evaluation of Factors Affecting Success Rate in Percutaneous Nephrolithotomy: A Five-Year Experience. J Urol Surg, 2023;10(3):245-252.

its results, and to evaluate the findings. In the current literature, the stone-free rate in PNL varies between 71% and 100% (3). This wide range in the success rates is due to the evaluation of stones of different sizes in studies and the different parameters and methods used in the assessment of success. Many factors such as stone size, density, complexity, anatomical variations, patient-related factors [age, body mass index (BMI), and comorbidities], as well as parameters such as entry point, access number, duration of operation, complication rates, and surgeon experience, are the main factors investigated regarding the success rates (4-6). Plain radiography, nephrography, or non-contrast abdominal computed tomography (NCCT) have been reported as diagnostic tools for detect stone -free rate after PNL in the current literature. In our study, the success rates following PNL were evaluated by CT.

In this retrospective study, we evaluated the stone-free rates and outcomes of patients who underwent PNL treatment in our clinic. We also analyzed factors related to the patient, stone, surgery, and several factors that may influence the success of PNL, with the aim of demonstrating which factors have a significant impact on the success rate. Identification and evaluation of these prognostic factors may play a prominent role in increasing the success of PNL.

Materials and Methods

The data of 508 patients who underwent PNL over a total of 5 years at our institute were analyzed retrospectively in terms of success rate. The demographic characteristics of the patients, accompanying comorbidities, stone characteristics, kidney characteristics, information on operation and hospitalization are shown in Table 1. Of the patients, 300 (59%) were male and 208 (41%) were female. The mean age was 42.89±16.57 years. In our study, various factors affecting the success rates of PNL operations were analyzed. These factors included patient's demographics, comorbidities, kidney features, stone characteristics, and operative information. The patients were evaluated with complete blood count, serum urea, creatinine, bleeding and coagulation profile, complete urinalysis, and urine culture before the operation. Detailed information about the operation was given to the patients, and informed consent forms were obtained from all patients. The patients were evaluated preoperatively with intravenous pyelography or non-contrast whole abdominal spiral tomography. The size of the stone is calculated by multiplying the maximum diameter by the diameter of the stone cut vertically with the help of a ruler in mm^2. Complex renal stones are defined as calculi greater than 3.0 cm in diameter with multiple renal stones, staghorn stones, abnormally positioned renal calculi, or horseshoe kidney calculi in a single kidney.

All patients were evaluated with NCCT scan for residual stones in the postoperative period. Post-PNL follow-up controls were performed at the 1st, 3rd, and 6th months. In the evaluation of success, the control results obtained in the first month, which is the period without any additional treatment, were taken as criteria. According to the postoperative period CT scan results, it was classified as "stone-free (SF)", "Clinically insignificant residual fragments (CIRFs)" and "failed (the presence of residual stones)". Asymptomatic, less than 4 mm, non-obstructing, and non-infected stones were evaluated as CIRF (7). Patients with SF and CIRF were considered successful cases.

Surgical Technique

All the operations were performed in the prone position. The pelvicalyceal system was visualized by administering radio-opaque material through the ureteral catheter under C-arm fluoroscopy. Under fluoroscopy, the relevant calyx was entered using 18 Gouge diamond-tipped percutaneous access needles (18G Percutaneous Access Needle, Boston Scientific). The tract was dilated through the guidewire using an 8F Amplatz dilator, 8F Teflon catheter, and 18F, 22F, and 30F Amplatz dilators over an 8F Teflon catheter, respectively. The access sheath (20-30F) (Amplatz sheat, Boston Scientific) was advanced up to the kidney and entered the collecting system. Under saline irrigation, the pelvicalyceal system was observed through the access sheath with a 26-F nephroscope. Stones detected in the pelvicalyceal system were fragmented with a pneumatic lithotripter (Vibrolith, Elmed).

Statistical Analysis

The analysis of the data was performed using the "SPSS for Windows 11.5" package program (185). Descriptive statistics were expressed as mean ± standard deviation or median (minimum-maximum) for continuous and discrete variables, and categorical variables as number of cases and percentile. The significance of the difference between the groups in terms of means was analyzed with the "Student's t-test" and the significance of the difference in terms of median values was investigated with the "Mann-Whitney U test". Categorical variables were evaluated with Pearson's "chi-square" or Fisher's "Exact Probability test". The significance of the linear relationship between continuous variables was analyzed by Spearman's "Correlation test". The combined effects of risk factors that had a significant effect on success and complications because of univariate statistical analyses or that were thought to have a significant effect in multivariate analyses were investigated with "Multiple Retroactively Eliminated Logistic Regression analysis". Odds ratio, 95% confidence interval, Wald statistics, and significance levels for each risk factor were calculated. Similarly, Multiple Linear Regression analysis was performed to determine the risk factors that had the most significant effect on the operation and dilatation times. The regression coefficient, standardized regression coefficient, 95% confidence interval, and significance levels for each risk factor were calculated. Variables found to be p<0.25 because of univariate analyses were included in the multiple regression models as candidate risk factors. Because the operation and dilatation times were not normally distributed, logarithmic transformation values were used in multiple linear regression analyses. The results were considered statistically significant for p<0.05.

Results

The mean stone burden was 9.78±13.5 cm² (4-78). Sixty-one percent of the stones were within the range of 3-15 cm². While simple stones constituted 53,15% (n=270) of the cases, the rate of complex stones was 46,85% (n=238). Mean operation time, fluoroscopy time, and length of hospital stay were respectively 102.25±38.64 minutes (28-270), 9.53±6.1 minutes (3-15), and 3.43±1.11 days (1-8). In the first month-evaluation, success was achieved in 427 of 508 patients who underwent PNL. The success rate was calculated as 84%. After additional treatments (58 ESWL, 4 repeat PNL, 11 ureteroscopy) were applied to 73 of 81 patients who were evaluated as a failure, the success rate increased to 86% in the postoperative third month and to 88% in the sixth month.

In the evaluation of first-month success rates, no difference was observed between the success and failure groups in terms of age, gender, socioeconomic status, and family history of stone disease. Furthermore, morbidities such as high BMI, hypertension, diabetes mellitus, hyperlipidemia, and heart disease had no effect on success. It was observed that the success rate decreased statistically in cases with accompanying macroscopic hematuria. The stone-free rate found in patients with a solitary kidney or congenital renal anomaly was statistically similar to patients without these pathologies. The history of previous kidney surgery and ESWL had no impact on the success rate. The success rate was found to be similar in patients with various degrees of hydronephrosis (Table 2).

While the success rate was similar for stones with a stone volume of less than 3 cm² and those between 3-15 cm², it was observed that the success rate decreased statistically significantly in stones larger than 15 cm². Although the success rate was 90.3% for simple stones, it was 76.9% for complex stones. The success rate between simple and complex stones was statistically significant (p=0.038). The lowest success rate among complex stones was observed in complete staghorn stones. Although the calyx entry point did not have a significant effect on success, it was noted that the success rate decreased significantly in stones requiring multiple attempts for entry.

Table 1. The demographics and stone characteristics of patients

Number of patients (n)	**508 patients**
Mean age (years)	42.89±16.57
<14	32 patients (6.29%)
14-65	428 patients (81.10%)
>65	48 patients (7.94%)
Male/Female	300/208 (1.44)
Body mass index (BMI)	26.45±4.01 kg/m²
<25	146 patients (28.74%)
25-30	282 patients (55.51%)
>30	80 patients (15.74%)
Hypertension	74 patients
Diabetes Mellitus	58 patients
Hyperlipidemia	56 patients
Heart disease	38 patients
Lung disease	18 patients
Solitary kidney	16 patients (3.1%)
Congenital renal anomaly	18 patients (5.5%)
Previous open surgery	78 patients (15.4%)
Previous ESWL	101 patients (19.9%)
Mean stone burden (cm²)	9.78±13.5 (1-125)
<3 cm²	n: 98 patients (19.29%)
3-15 cm²	n: 314 patients (61.8%)
>15 cm²	n: 96 patients (18.8%)
Simple Stones	n: 270 (53.15%)
Lower Calyx	n: 106 patients (20.9%)
Middle Calyx	n: 8 patients (1.5%)
Upper Calyx	n: 16 patients (3.5%)
Pelvis Renalis	n: 122 patients (20.3%)
Upper Ureter	n:18 patients (5.6%)
Complex Stones	n: 238 (46.85%)
Parsiel Coralliform	n: 56 patients (11%)
Complex Coralliform	n: 66 patients (13%)
Multiple Calyx	n: 116 patients (22.8%)
Mean operation time (minute)	102.25±38.64 (28-270)
Mean scopy duration (minute)	9.53±6.1 (3-15)
Mean nephrostomy time (day)	3.23±1.11 (1-8)
Mean hospitalization (day)	3.43±1.45 (1-14)

Table 2. Evaluation of factors on success rate					
Age (Years)					
<14	27	75.0	5	25.0	0.832
14-65	365	85.3	63	14.7	
>65	35	73	13	27	
Gender					
Male	249	83	51	17	0.534
Female	178	85	30	15	
Socioeconomic status					
High	200	79.7	51	20.3	0.114
Low	227	88.3	30	11.7	
Family Stone					
Yes	341	85.2	59	14.8	0.481
No	86	85.2	22	20.4	
Body mass index (BMI)					
<25	125	85.0	21	14.4	0.407
25-30	245	82	54	18	
>30	57	90.5	6	9.5	
Hypertension					
Yes	287	82.7	60	17.3	0.345
No	140	87.0	21	13.0	
Diabetes mellitus					
Yes	378	80.2	74	19.8	0.608
No	49	87.5	7	12.5	
Hyperlipidemia					
Yes	300	85.2	52	14.8	0.678
No	127	81.4	29	18.6	
Hearth disease					
Yes	382	81.4	74	18.6	0.123
No	45	86.5	7	13.5	
Lung disease					
Yes	404	83.5	80	16.5	0.351
No	23	95.6	1	4.4	
Macroscopichematuria					
Yes	352	88	48	12	**0.032**
No	75	69.4	33	30.6	
Serum urea					
<40	386	84.8	69	15.2	0.223
>40	41	77.3	12	22.6	
Serum creatinine					
<1.3	395	84.4	73	15.6	1.000
>1.3	32	84.2	6	15.8	
Solitary kidney					
Yes	414	84.1	78	15.9	0.489
No	13	81.3	3	18.7	
Congenital renal anomaly					

Table 2. continued					
Age (Years)					
Yes	402	83.8	78	16.2	0.234
No	25	89.3	3	10.7	
Previous open surgery					
Yes	362	82.1	68	17.9	0.224
No	65	83.3	13	16.7	
ESWL					
Yes	304	83.5	60	20.2	0.786
No	123	85.4	21	14.6	
Hydronephrosis grade					
0-1	200	87	30	13	0.178
2-3	227	81.6	51	18.4	
Stone Size (cm²)					
<3	92	89.3	6	10.7	**<0.001**
3-15	294	89.8	20	10.2	
>15	41	48.1	55	51.9	
Simple Stone	244	90.3	26	9.7	**0.038^**
Complex Stone	183	76.9	55	23.1	
Parsiel Coralliform	47	79.7	12	20.3	
Complex Coralliform	35	60.3	23	39.7	
Multiple Calyx	101	83.5	20	16.5	**0.023&**
Access Point					
Lower Calyx	310	87.8	43	12.2	**0.032**
Mid Calyx	55	82	12	18	
Upper Calyx	25	75.8	8	24.2	
Multiple Access	37	67.3	18	32.7	
Stone Composition					
Ca-phosphate	41	82	9	18	**0.014*** **0.010+**
İnfection	23	62.2	14	37.8	
Ca ox monohydrate	184	89.3	22	10.7	
Cystine	16	59.3	11	40.7	
Others (Ca ox dihydrate, Uric acid, mix)	163	86.7	25	13.3	
Intraoperative complication					
Yes	360	88.5	47	11.5	**0.022**
No	67	66.3	34	33.7	
Operative time (minute)					
<100	264	88	36	12	**0.030**
>100	163	69.6	45	30.4	
Surgeon's experience					
0-254	190	74.8	64	25.2	**0.036**
255-508	237	93.3	17	6.7	

^ p value between simple and complex stones
& p value among complex stones
*p value between Ca-phosphate and infection stones
+ p value between Ca-phosphate and cysteine stones

It was also seen that the structure of the stone had an impact on the success. The lowest success rate was observed in cystine stones (59.3%) (p=0.010). The success rate was also found to be lower in infection stones compared with other types of stones (62.2%) (p=0.014). It was observed that intraoperative complications and long operation time significantly affected the success rate (p=0.022, p=0.030). The success rate was 74.8% in our first 254 cases, and it reached 93% in the last 254 cases. It was found that increased surgical experience was a factor that had a statistically significant effect on success (p=0.036). Combined effects of risk factors were also evaluated. According to the results of the retrospective logistic regression analysis, surgeon's experience, stone structure, complexity of the stone, and stone size were found to be independent factors affecting the success rate.

Complications associated with PNL were classified as major and minor complications. Major complications developed in 8.3% of the patients who underwent PNL operations, whereas minor complications occurred in 21.3%. As a major complication, bleeding requiring transfusion was encountered and 5.5% (n=28) of the cases. Three patients required conversion to open surgery due to bleeding and four patients due to access failure. Collecting system damage occurred in three patients, which required Double J insertion as an additional treatment. Hemothorax occurred in two patients which were managed with thoracal drainage. An arteriovenous fistula was observed in two patients and treated with superselective embolization.

Discussion

PNL provides the highest stone-free rate for treating kidney stones and with the effect of technological devices developed recently, has become the treatment of choice for complex and large kidney stones (3). The main goal of PNL is to achieve stone-free status with minimal morbidity with a high success rate. In a recent meta-analysis, PNL in the surgical treatment of kidney stones was shown to have the highest success and stone-free rate compared with other treatment options such as ESWL and retrograde intrarenal surgery (2). PNL has a near 100% success rate for treating non-staghorn stones, and up to 85% in staghorn stones (8). In our study, a total success rate of 84% was observed at 1-month follow-up in 508 patients undergoing PNL. In the current literature, different imaging techniques and success criteria's have been defined in the assessment of PNL success (9). In our study, success rates were assessed using NCCT because commonly used imaging modalities, such as plain abdominal radiography (KUB film) or ultrasonography were reported as deficient for the diagnosis of small residual fragments (10). The question of whether small stones that are not clinically important (i.e., do not cause obstruction, pain, and infection in the urinary system) overshadow the success of the operation has been enquired and the concept of clinically insignificant residual fragments (CIRFs) has been put forward. In this concept, the stone size was limited to 4 mm, and it was concluded that stones below this size had no effect on the success of the operation as it has been determined that 85% of stones of this size will pass without causing clinically symptomatic pain (11). We also evaluated stones below 4 mm as a successful group. Many factors shown in the literature to influence the success of PNL have been evaluated in various studies (5). We evaluated the impact of several factors on the success rate of PNL. A prospective study by Olbert et al. (12) showed that age and gender had no effect on success rates. We also found that age, gender, socioeconomic status, and family history has got no effect on the PNL success. No studies have investigated the impact of socioeconomic status and family history on PNL outcomes. In our study, similar to demographic characteristics, comorbidities such as hypertension, diabetes, hyperlipidemia, KVH, and BMI did not significantly affect surgical outcomes. Alyami et al. (13) found no difference on stone -free rate based on BMI. In a study of 430 cases conducted by Tefekli et al. (14), patients with metabolic syndrome and its components such as hypertension, diabetes, hyperlipidemia, and obesity were evaluated, and similar success rates were reported. We also did not demonstrate a significant effect of higher serum urea, creatinine levels, or presence of a solitary kidney and congenital renal anomaly on success rates. The global percutaneous nephrolithotomy study group showed that renal congenital abnormalities do not significantly impact treatment outcomes (15). It has also been also shown that PNL can be performed with similar success and complication rates in patients with solitary kidneys (16). In our study, we observed that previous surgery and a history of ESWL had no significant effect on the success rate. Patients with a history of open stone surgery reported as have a lower chance of stone-free rate in the current literature (4). Basiri et al. (17) stated that an open surgical history on the same side did not affect the success or complication rates in patients treated with PNL. Yuruk et al. (18) reported that similar success and complication rates could be achieved with PNL after failed ESWL, but it was usually more difficult with a prolonged operative time and fluoroscopic screening time. In our study, the success rate was significantly lower in cases with accompanying macroscopic hematuria. There was no statistically significant difference in success rates between patients with a higher degree of hydronephrosis and those with a lower degree of hydronephrosis. In hydronephrotic systems with stones, the entrance is easy, but the rate of failure increases because the stones can escape to other calyces (19). We found that stone size, complexity, and structure were the most important predictors of stone-free rate after PNL. Complex stones accounted for almost half (46.85%) in our cases. Our results are consistent with those of Knox et al. (20), who revealed that stone sizeand number, are associated with reduced stone clearance. Bagrodia et al. (21) reported that stone size was the only independent predictor of treatment success. Yamasaki (22) reported that the size of the stone, the location, and the presence of multiple stones were prognostic factors for stone recurrence. Notably, in contrast to these observations, the European Association of Urology guidelines on urolithiasis discuss that the treatment success of PCNL is hardly affected by stone size (23). In our study, it was determined that the success rate in cysteine and infection stones was lower than other stone compositions. A reason for the low success rate of infected stones may be that these tend to be large and even coralliform. The best of our knowledge, there is no study evaluating the impact of stone composition on the success of PNL in the current literature. The success rate of multifocal access is expected to be lower as the stones-requiring multifocal intervention are larger and more complex. In this study, a higher number of accesses was performed in the failed group, confirming that a higher number of accesses was associated with less favorable outcomes. We demonstrated that higher intraoperative complication rates, prolonged dilation, and operative time reduced the success rate of PNL. The experience of the surgeon and learning curve are also important factors affecting the overall surgical success. In our series, the first 204 cases had a success rate of 73.8, whereas the latter 204 cases had a success rate of 93%. In line with our results, Tanriverdi et al. (23) reported a success rate of 73% for the first 60 cases and 85% after 60 cases. Although PNL is a significant treatment option with a high success rate, it should not be forgotten that serious complications can occur, even to the point of being life-threatening. The rate of major complications such as urosepsis, bleeding necessitating intervention, pleural injury, and colonic injury was reported to be between 0.2% and 4.7% fin a large study with 5803 cases (24). In our study, the rate of major complications was 8.3%. Bleeding was the most common complication. The rate of renal hemorrhage requiring transfusion and 5.5%. Transfusion rates ranging up to 20% have been documented with an overall of 7% demonstrated in a systematic review (25).

Study Limitations

Our study has some limitations that need to be considered while evaluating its findings. First, it is a retrospective study that can be affected by all potential weaknesses stemming from its retrospective design. Second, it has a relatively low number of cases and short evaluation time of success compared to clinical trials with high number of cases in the current literature.

Conclusion

PNL surgery is an effective and minimally invasive method that requires surgical experience and can be safely applied to stone treatment with adequate equipment and experience, at least as successfully as open surgery. After reviewing our experience with PNL, we showed several clinical and stone factors related to the success rate after PNL. Stone size, complexity, and composition, surgeon's experience were the independent predictors of stone-free status after PNL.

Ethics

Ethics Committee Approval: The study protocol was approved by Health Sciences University Dışkapı Yıldırım Beyazıt Training and Research Hospital Clinical Research Ethics Committee (project no: 24/07, date: 18.04.2011).

Informed Consent: Informed consent forms were obtained from all patients.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: S.Y., M.T., F.D., Concept: S.Y., M.T., F.D., Design: S.Y., M.T., F.D., Data Collection or Processing: S.Y., M.T., F.D., Analysis or Interpretation: S.Y., M.T., F.D., Literature Search: S.Y., M.T., F.D., Writing: S.Y., M.T., F.D.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declare that they have no relevant financial.

References

1. Türk C, Petřík A, Sarica K, Seitz C, Skolarikos A, Straub M, Knoll T. EAU Guidelines on Interventional Treatment for Urolithiasis. Eur Urol 2016;69:475-482.
2. Chung DY, Kang DH, Cho KS, Jeong WS, Jung HD, Kwon JK, Lee SH, Lee JY. Comparison of stone-free rates following shock wave lithotripsy, percutaneous nephrolithotomy, and retrograde intrarenal surgery for treatment of renal stones: A systematic review and network meta-analysis. PLoS One 2019;14:e0211316.
3. De S, Autorino R, Kim FJ, Zargar H, Laydner H, Balsamo R, Torricelli FC, Di Palma C, Molina WR, Monga M, De Sio M. Percutaneous nephrolithotomy versus retrograde intrarenal surgery: a systematic review and meta-analysis. Eur Urol 2015;67:125-137.
4. Smith A, Averch TD, Shahrour K, Opondo D, Daels FP, Labate G, Turna B, de la Rosette JJ; CROES PCNL Study Group. A nephrolithometric nomogram to predict treatment success of percutaneous nephrolithotomy. J Urol 2013;190:149-156.
5. Jiang K, Sun F, Zhu J, Luo G, Zhang P, Ban Y, Shan G, Liu C. Evaluation of three stone-scoring systems for predicting SFR and complications after percutaneous nephrolithotomy: a systematic review and meta-analysis. BMC Urol 2019;19:57.

6. de la Rosette JJ, Zuazu JR, Tsakiris P, Elsakka AM, Zudaire JJ, Laguna MP, de Reijke TM. Prognostic factors and percutaneous nephrolithotomy morbidity: a multivariate analysis of a contemporary series using the Clavien classification. J Urol 2008;180:2489-2493.

7. Rassweiler JJ, Renner C, Eisenberger F. The management of complex renal stones. BJU Int 2000;86:919-928.

8. Falahatkar R, Shahraki T, Falahatkar S, Esmaeili S, Mashouf P. Evaluating outcomes of complete supine percutaneous nephrolithotomy for staghorn vs multiple non-staghorn renal stones: a 10-year study. World J Urol 2021;39:3071-3077.

9. Skolarikos A, Papatsoris AG. Diagnosis and management of postpercutaneous nephrolithotomy residual stone fragments. J Endourol 2009;23:1751-1755.

10. Pires C, Machet F, Dahmani L, Irani J, Dore B. Sensibilité de la radiographie de l'abdomen sans préparation par rapport à la tomodensitométrie dans l'évaluation des fragments résiduels après NLPC [Sensitivity of abdominal radiography without preparation compared with computed tomography in the assessment of residual fragments after percutaneous nephrolithotomy]. Prog Urol 2003;13:581-584.

11. Segura JW, Preminger GM, Assimos DG, Dretler SP, Kahn RI, Lingeman JE, Macaluso JN Jr, McCullough DL. Nephrolithiasis Clinical Guidelines Panel summary report on the management of staghorn calculi. The American Urological Association Nephrolithiasis Clinical Guidelines Panel. J Urol 1994;151:1648-1651.

12. Olbert PJ, Hegele A, Schrader AJ, Scherag A, Hofmann R. Pre- and perioperative predictors of short-term clinical outcomes in patients undergoing percutaneous nephrolitholapaxy. Urol Res 2007;35:225-230.

13. Alyami FA, Skinner TA, Norman RW. Impact of body mass index on clinical outcomes associated with percutaneous nephrolithotomy. Can Urol Assoc J 2013;7:E197-201.

14. Tefekli A, Kurtoglu H, Tepeler K, Karadag MA, Kandirali E, Sari E, Baykal M, Muslumanoglu AY. Does the metabolic syndrome or its components affect the outcome of percutaneous nephrolithotomy? J Endourol 2008;22:35-40.

15. Osther PJ, Razvi H, Liatsikos E, Averch T, Crisci A, Garcia JL, Mandal A, de la Rosette J; Croes PCNL Study Group. Percutaneous nephrolithotomy among patients with renal anomalies: patient characteristics and outcomes; a subgroup analysis of the clinical research office of the endourological society global percutaneous nephrolithotomy study. J Endourol 2011;25:1627-1632.

16. Mahboub MR, Shakibi MH. Percutaneous nephrolithotomy in patients with solitary kidney. Urol J 2008;5:24-27.

17. Basiri A, Karrami H, Moghaddam SM, Shadpour P. Percutaneous nephrolithotomy in patients with or without a history of open nephrolithotomy. J Endourol 2003;17:213-216.

18. Yuruk E, Tefekli A, Sari E, Karadag MA, Tepeler A, Binbay M, Muslumanoglu AY. Does previous extracorporeal shock wave lithotripsy affect the performance and outcome of percutaneous nephrolithotomy? J Urol 2009;181:663-667.

19. Lu Z, Dong Z, Ding H, Wang H, Ma B, Wang Z. Tamsulosin for ureteral stones: a systematic review and meta-analysis of a randomized controlled trial. Urol Int 2012;89:107-115.

20. Knox ML, Cantor AM, Bryant JE, Burns JR. Predictive factors for percutaneous nephrolithotomy outcomes in neurogenic bladder population. J Endourol 2012;26:823-827.

21. Bagrodia A, Gupta A, Raman JD, Bensalah K, Pearle MS, Lotan Y. Predictors of cost and clinical outcomes of percutaneous nephrostolithotomy. J Urol 2009;182:586-590.

22. Yamasaki A. [Long-term results of endourological treatment of urinary calculi: multivariate analyses of the risk factors related to recurrence or re-growth]. Nihon Hinyokika Gakkai Zasshi 1994;85:1601-1609.

23. Tanriverdi O, Boylu U, Kendirci M, Kadihasanoglu M, Horasanli K, Miroglu C. The learning curve in the training of percutaneous nephrolithotomy. Eur Urol 2007;52:206-211.

24. de la Rosette J, Assimos D, Desai M, Gutierrez J, Lingeman J, Scarpa R, Tefekli A; CROES PCNL Study Group. The Clinical Research Office of the Endourological Society Percutaneous Nephrolithotomy Global Study: indications, complications, and outcomes in 5803 patients. J Endourol 2011;25:11-17.

25. Seitz C, Desai M, Häcker A, Hakenberg OW, Liatsikos E, Nagele U, Tolley D. Incidence, prevention, and management of complications following percutaneous nephrolitholapaxy. Eur Urol 2012;61:146-158.