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Comparison of Success and Complication Rates of Percutaneous Nephrolithotomy Operations According to Kidney Stone Localization

Böbrek Taş Lokalizasyonuna Göre Perkütan Nefrolitotomi Operasyonlarının Başarı Ve Komplikasyon Oranlarının Karşılaştırılması

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ÖZET

Amaç: Perkütan nefrolitotomi (PNL), büyük ve kompleks böbrek taşları için birinci basamak cerrahi tedavi yöntemidir, ancak potansiyel morbidite ve ciddi komplikasyonlar gelişebilmektedir. Bu nedenle çalışmamızda geniş örneklem grubunda PNL sonrası taş lokalizasyonuna göre başarı ve komplikasyon oranlarını değerlendirmeyi amaçladık.

Gereç ve Yöntemler: Bu çalışmaya PNL uygulanan toplam 782 hasta retrospektif olarak dahil edilmiştir. Hastalar iki ana gruba ayrıldı; basit taş grubu (üst pol, pelvis, alt pol) ve kompleks taş grubu (parsiyel staghorn, multikalisyel, pelvis+alt pol, komplet staghorn). Tüm olgularda operasyon süresi, floroskopi süresi, hastanede yatış süresi ve nefrostomi kateteri çıkarma zamanı kaydedildi.

Bulgular: Olgularda taşların %67,1'i (n=525) basit taşlarken, %32,9'u (n=257) kompleks taşlardı. Çalışmamızda en sık %34,3 oranıyla alt kaliks taşı gözlendi. Olguların %15,1'inde kan transfüzyonu gerçekleştirildi. Kompleks taşa sahip olgularda ölçülen ortalama akses sayısı, operasyon süresi, floroskopi süresi, nefrostomi alınma zamanı ve hastanede yatış sürelerinin, basit taş gözlenen gruba kıyasla anlamlı şekilde yüksek olduğu belirlenmiştir (Sırasıyla p-değerleri = 0.000, 0.000, 0.009, 0.000 ve 0.000). Total komplikasyon oranı %9,7 (n=36) olarak belirlenirken; en sık komplikasyon (%4,4) ciddi kanama idi. Çalışmamızda total başarı oranı %74,6 (n=583) olarak belirlendi. Kompleks taşa sahip olgularda hesaplanan komplikasyon oranının (%14.4), basit taş gözlenen gruba (%7.4) kıyasla istatistiksel olarak anlamlı olacak şekilde yüksek (p=0.002), taşsızlık oranlarının (sırasıyla; 57.6% ve 82.9%) ise düşük olduğu belirlendi (p=0.000).

Sonuç: Çalışmamızda PNL prosedürünün basit taşa sahip olgularda, kompleks taşlı gruba kıyasla anlamlı şekilde yüksek başarı oranı ve düşük komplikasyon riski sağladığı açıkça gösterilmiştir. PNL, basit taşlı olgularda daha kısa ameliyat süresi ve hastanede yatış ile anlamlı olarak ilişkilendirilmiştir. Ayrıca geniş örneklem grubuna sahip çalışmamızın bulguları, yayınlanmış verilerle karşılaştırıldığında nispeten yüksek taşsızlık oranı ve düşük komplikasyon oranları gözlenmiştir.

Anahtar Kelimeler: Böbrek taşı; Ürolitiyazis; Perkütan nefrolitotomi; Taşsızlık oranı; Komplikasyon.

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Approval was received for this study from the İstinye University Human Research Ethics Committee Institutional Review Board protocol approval number: 23/199, date: 08.08.2023. The ethical rules of the Declaration of Helsinki were followed in the study protocol.

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ABSTRACT

Objective: Percutaneous nephrolithotomy (PNL) is first-line treatment modality for large and complex stones, however it is associated with potential morbidity and severe complications. Therefore, we aimed to evaluate the success and complication rates according to stone localization in large sample group following PNL.

Material and Methods: Total number of 782 patients who underwent PNL, were included in this retrospective multicenter study. Patients were divided into two major groups; simple stones group (upper pole, pelvis, lower pole) and complex stones group (partial staghorn, multi-caliceal, pelvis+lower pole, complete staghorn). Surgery time, fluoroscopy time, complications, hospitalization and nephrostomy catheter removal day were recorded.

Results: In our study, 525 cases (67.1%) had simple stones, 257 (32.9%) complex stones. The most frequent (34.3%) stone localization was lower pole. Overall blood transfusion rate was 15.1%. Significantly increased in mean number of accesses, surgery time, fluoroscopy time, nephrostomy removal time and hospitalization documented in cases with complex stones (p-values = 0.000, 0.000, 0.009, 0.000 and 0.000, respectively). Overall complication rate was 9.7% (n=76) and the most frequent complication (4.4%) was severe hemorrhage. Overall stone-free rates (SFR) are 74.6% (n=583). Furthermore, complication rate (14.4% vs. 7.4%) was statistically higher and SFR (57.6% vs. 82.9%) was lower in cases with complex stones than simple stones (p-values = 0.002 and 0.000, respectively).

Conclusions: Our findings clearly demonstrated that PNL achieved higher success rate and lower complication risk in patients with simple stones than complex stones. PNL is significantly associated with shorter operation duration and hospitalization in simple stones group. Furthermore, PNL provided relatively higher overall SFR and lower complication rates in our large sample group compared to the published data.

Keywords: Kidney stones; Urolithiasis; Percutaneous nephrolithotomy; Stone-free rates;

INTRODUCTION

Urolithiasis is a widespread disease with increasing prevalence, varies from 5 % to 20 % worldwide. The factors contributing to urinary stone formation are multi-factorial involving metabolic, genetic, anatomic, and environmental factors (1,2). Decision of the appropriate treatment strategy for kidney stone is based on stone size, density, localization, type, occlusion characteristics of stone, and kidney anatomy (3).

As kidney stone often recurs after intervention, the main goal of urinary stone treatment is to achieve higher stone-free rates (SFR) and decrease morbidity. Treatment modalities for urolithiazis include extracorporeal shock wave lithotripsy (ESWL), percutaneous nephrolithotomy (PNL, mini PNL), ureteroscopy, retrograde intrarenal surgery (RIRS), open or laparoscopic ureterolithotomy (4). Nowadays PNL is common first-line treatment procedure applied for large (typically > 2 cm) and complex kidney stones, which currently recommended by Urolithiasis Guideline of European Association of Urology (EAU) (5).

Although PNL provides significantly higher SFR with efficient stone extraction in the management of urinary tract stones, it is still associated with higher morbidity and potential severe complications particularly hemorrhage, infection, and death (6). Additionally, hemorrhage represents one of the most frequent and potential complication of difficult management following PNL (7). Therefore, in present study, we aimed to evaluate the success and complication rates according to stone localization in large sample group following percutaneous nephrolithotomy.

MATERIAL AND METHODS

Sample

This study was performed with the Institutional Review Board protocol approval date 08.08.2023 and number 23/199 in İstinye University. Total number of 782 patients (aged between 6-81 years old) who underwent PNL between January 2014 to January 2023, were included in this retrospective multicenter

study. Patients were divided into two major groups; simple stones group (Group 1) included the cases with kidney stone localized in upper pole, pelvis, lower pole and patients with partial staghorn, multi-caliceal, pelvis + lower pole, complete staghorn calculi represent complex stones group (Group 2). Patients with ectopic kidney, horseshoe kidney, pyelonephritis, kidney transplant, chronic renal failure, coagulopathy were excluded from present study.

Patients' demographic characteristics, detailed anamnesis (ESWL history /open nephrolithotomy history /PNL history), presence of comorbidity, physical examination findings, BMI, laboratory findings and PNL side were recorded. All patients were routinely evaluated with abdominal X-ray, computerized tomography (CT), intravenous pyelography or ultrasonography pre- and postoperatively. Urine culture, hemogram, renal function (urea, creatinine, vs) coagulation tests were performed and stone surface area (mm^2) were recorded preoperatively for all patients. The surface area of the stones were calculated with [(height × width × π) / 4] formula. The exact surgery time, fluoroscopy time, hospitalization time and nephrostomy catheter removal day as well as access number were recorded. Hemogram analyzes were performed at post-operative 1^{st} hour and at intervals thereafter, depending on the bleeding status. Hemogram and biochemical analyzes were also performed post-operatively at the 24^{th} hour for all patients.

PNL Technique

PNL was performed under general anesthesia by experienced urologists in the lithotomy position. Subsequently insertion of 5F/6F ureteral catheter, patients turned to the prone position. Immediately after, fluoroscopic-guided percutaneous access performed and dilatation was achieved by amplatz or balloon dilatators. 18-22 French (F) (Wolf®, Richard Wolf, GmbH, Germany) nephroscopes and 24-26 F (Storz®, Karl Storz Endoskope, Tuttlingen, Germany) rigid nephroscopes were used for operations. Flexible cystoscope, holmium laser and basket catheter were not utilized in all operations. Stones were fragmented via pneumatic lithotriptors or ultrasonic + pneumatic lithotriptors. Absence of stones in x-ray/CT imaging or detection of stones < 4 mm 24 hours after surgery was considered stone-free. Additionally, complications were classified according to the Modified Clavien classification in post-operative period. Severe hemorrhage was defined as abundant bleeding during operation, hemoglobin value less than 10 g/dL or reduction 3 units in hemoglobin after the operation.

Statistical Analysis

All the data were analysed with SPSS (Statistical Package for the Social Sciences) software for Windows (v21.0; IBM, Armonk, NY, USA). Individual and aggregate data were summarized using descriptive statistics including mean, standart deviations, medians (min-max), frequency distributions and percentages. Normality of data distribution was verified by Kolmogorov-Smirnov test. Comparison of the variables with normal distribution was made with Student t test. The variables which were not normally distributed, the Mann Whitney and Kruskal Wallis tests were conducted to compare between groups. Evaluation of categorical variables was performed by Chi-Square test. P-values of < 0.05 were considered statistically significant.

RESULTS

The 782 PNL patients included in this study were 319 females (40.8%) and 463 males (59.2%). The mean age was 41.6±15.0 years (Ranged =6-81 years) in our sample group. General clinical characteristics of sample group is presented in Table 1. The PNL side was left kidney in 50.9% (n=398) of the cases, while 49.1% (n=384) were right kidney. It was documented that 67.1% (n=525) of the cases had simple stones, 32.9% (n=257) had complex stones. The most frequent stone localization was lower pole with a rate of 34.3% (n=268); and followed by pelvis (22.1%, n=173), and pelvis + lower pole (12.4%, n=97) respectively. Previous history of ESWL, open nephrolithotomy, PNL is also presented in Table 1. History of open nephrolithotomy rate was

found statistically higher in patients with complex stone than patients with simple stone (11.6% vs. 17.1%) (p=0.034). In addition 460 (58.8%) patients had preoperative hydronephrosis (Table 1).

The mean pre- and post-operative hemoglobin change was 2.06±4.69 mg/dl, and the hematocrit change was 5.4±5.6 %. Overall blood transfusion rate was 15.1% (n=118) during postoperative period. However, preoperative hemoglobin (13.8±1.8 vs. 13.0±1.9 mg/dl) and hematocrit values (40.7±5.7 vs. 38.3±6.5%) of the patients who received blood transfusions were found to be statistically lower than the patients who didn't receive blood transfusions (p-values = 0.000 and 0.000, respectively) (Figure 1).

The median (IQR) stone surface was measured as 592.6 (38-9410) mm^2 in total patients. Mean stone surface area was significantly higher in patients with complex stone compared to the patients with simple stones (p-values: 0.000) (Figure 2) (Table 2).

According to the the perioperative characteristics; of the cases 77.9% (n=609) underwent one access, 16.1% (n=126) two accesses, 5.9% (n=46) 3 accesses and in 1 patient (0.1%) 4 accesses utilized to access. The median (IQR) surgery time was 120.0 (3-300) minutes, fluoroscopy time 4.4 (0-46) minutes, hospitalization time 4.0 (1-34) days, and the nephrostomy catheter removal time was 3.0 (1-18) days in our sample group. In addition, detected significantly increased in mean number of access, surgery time, fluoroscopy time, nephrostomy removal time and hospitalization time documented in cases with complex stones (p-values = 0.000, 0.000, 0.009, 0.000 and 0.000, respectively) (Figure 3) (Table 2).

Overall complication rate was 9.7% (n=76) in our study. Complication and treatment distribution of our cases according to Modified Clavien classification is presented in Table 3. The most frequent complication was severe hemorrhage with a rate of 4.4% (n=35); and followed by simple hemorrhage (1.5%), and persistent urine leakage (1.1%) in present study (Table 3).

Overall SFR is 74.6% (n=583) in present study. Furthermore, complication rate was statistically higher in cases with complex stones (14.4% vs. 7.4%) compared to the group with simple stones (p=0.002). Similarly, SFR was found to be statistically lower in cases with complex stones (57.6% vs. 82.9%) compared to the group with simple stones (p=0.000) (Figure 4) (Table 4).

Table 1. Clinical characteristics of cases.

	Clinical Variables	Groups		PNL Total	p-value
		Simple Stones (n=525, 67.1%)	Complex Stones (n=257, 32.9%)	(n=782)	
Age	Mean±SD	42.1±15.0	40.6±14.9	41.6±15.0	0.112
BMI	Mean±SD	26.2±5.3	26.2±5.6	26.2±5.4	0.906
Gender n (%)	Male Female	316 (60.2) 209 (39.8)	147 (57.2) 110 (42.8)	319 (40.8) 463 (59.2)	0.424
PNL Side n(%)	Right Left	268 (51.0) 257 (49.0)	116 (45.1) 141 (54.9)	398(50.9) 384(49.1)	0.120
ESWLHistory n(%)	No Yes	390 (74.3) 135(25.7)	194 (75.5) 63 (24.5)	584 (74.7) 198 (25.3)	0.717
Open Nephrolithotomy	No Yes	464 (%88.4) 61 (%11.6)	213 (%82.9) 44 (%17.1)	677 (86.6) 105 (13.4)	**0.034***
Percutaneous Nephrolithotomy	No Yes	499 (%95.0) 26 (%5.0)	239 (%93.0) 18 (%7.0)	738 (94.4) 44 (5.6)	0.242
Pre-op hydronephrosis	No Yes	218 (%41.5) 307 (%58.5)	104 (%40.5) 153 (%59.5)	322 (41.2) 460 (58.8)	0.778

* = p<0.05 statistically significant

Table 2. Comparison of perioperative and postoperative variables between the groups.

	n	Access No	Stone surface (mm^2)	Surgery time (min.)	Fluoroscopy time (min.)	Nephrostomy catheter remove (day)	Hospitalization time (days)
		Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)
Simple Stones	525	1.0 (1-3)	500.8 (38-9410)	110.0 (15-300)	4.0 (0-46)	2.0 (1-18)	4.0 (1-34)
Upper pole	84	1.0 (1-3)	557.3 (138-9410)	110.0 (15-300)	3.2 (0.6-26)	2.0 (1-13)	4.0 (2-12)
Pelvis	173	1.0 (1-3)	490.6 (38-6280)	102.5 (25-300)	4.1 (0-31)	3.0 (1-18)	4.0 (2-34)
Lowerpole	268	1.0 (1-3)	500.8 (70-4415)	120.0 (30-240)	4.3 (0.1-46)	2.0 (1-11)	4.0 (1-19)
Complex Stones	257	2.0 (1-4)	769.3 (113-4945)	120.0 (3-300)	5.0 (0.5-45)	3.0 (1-17)	5.0 (2-17)
Partial staghorn	62	1.0 (1-3)	785.0 (235-4945)	120.0 (3-240)	4.4 (0.5-22)	2.0 (1-7)	4.0 (2-11)
Multi-caliceal	52	2.0 (1-3)	765.3 (157-2119)	130.0 (60-240)	6.1 (0.7-45)	3.0 (1-7)	5.0 (2-16)
Pelvis + LowerPole	97	1.0 (1-3)	690.8 (113-4945)	120.0 (15-270)	4.4 (0.7-20)	3.0 (1-17)	5.0 (2-17)
Complete staghorn	46	3.0 (1-4)	588.7 (138-2826)	180.0 (70-300)	6.0 (1-33)	3.5 (1-7)	5.0 (2-12)

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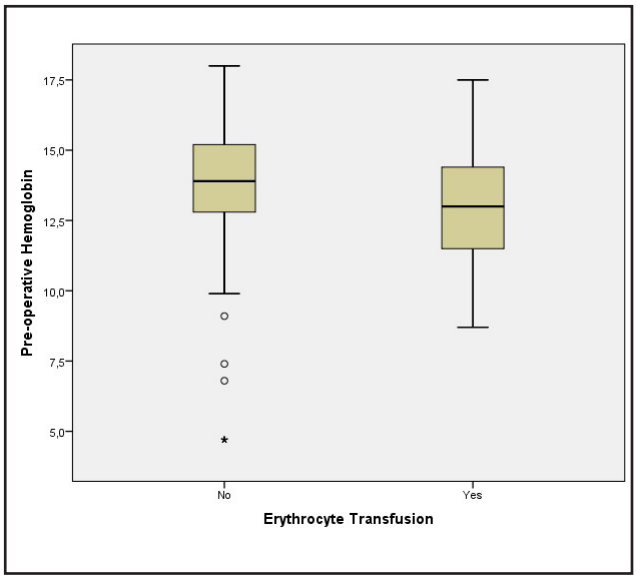

Figure 1. Comparison of pre-operative hemoglobin levels between groups with and without blood transfusion.

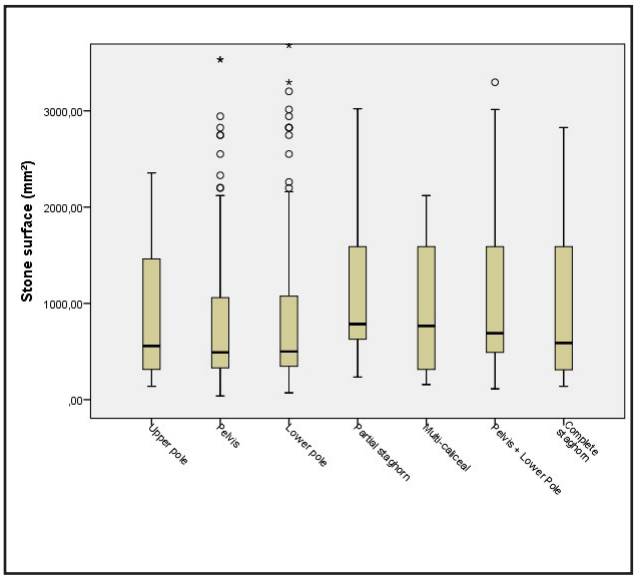

Figure 2. Comparison of mean stone surface between groups.

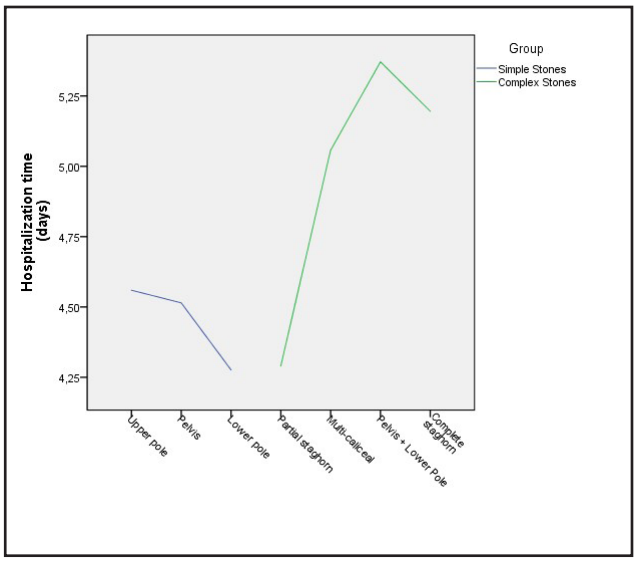

Figure 3. Comparison of mean hospitalization time between groups.

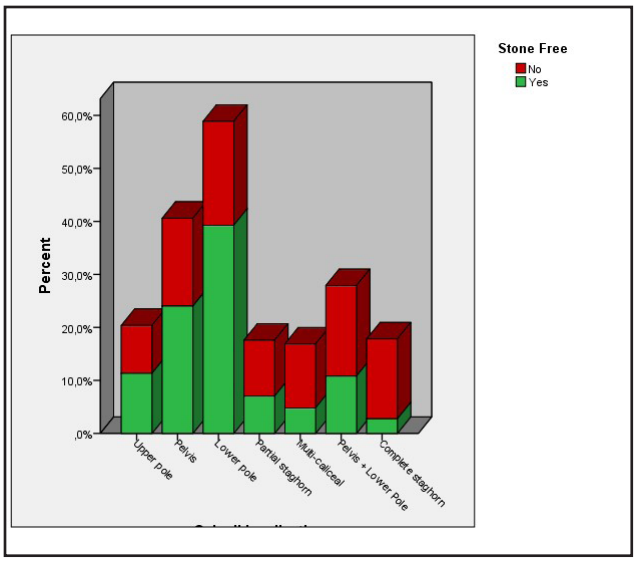

Figure 4. Comparison of stone-free rates between groups.

Table 3. Complications according to Modified Clavien Classification.

	Complication	n (%)	Treatment
Grade 1	Hemorrhage	12 (1.5)	Conservative Treatment
Grade 2	Severe hemorrhage	35 (4.4)	Blood Transfusion
	Pneumonia	3 (0.3)	Antibiotic Treatment
	Cellulite in the Lumbar Region	2 (0.2)	Antibiotic Treatment
Grade 3a	Pelvis Perforation	2 (0.2)	Double-J stent placement > 6 week
	Persistent Urine Leakage	9 (1.1)	Double-J stent placement > 4 week
	Hemothorax	3 (0.3)	Chest Tube Insertion
Grade 3b	Perirenal hematoma	5 (0.6)	Selective Angioembolization
Grade 4a	Life-threatening hemorrhage	1 (0.1)	Nephrectomy
	Colon Perforation	1 (0.1)	Primary repair, Colostomy
	Jejunal Perforation	1 (0.1)	Primary repair
Grade 4b	Urosepsis	4 (0.5)	Antibiotic Treatment

Table 4. Comparison of complication and stone-free rates between the groups.

	Complication (n%)		P-value	Stone Free (n%)		P-value
	No	Yes		No	Yes	
Simple Stones	486(%92.6)	39(%7.4)	**0.002***	90(%17.1)	435(%82.9)	**0.000***
Upperpole	68 (%9.6)	16(%21.1)		18 (%9.0)	66 (%11.3)	
Pelvis	164 (%23.2)	9(%11.8)		33(%16.6)	140(%24.0)	
Lowerpole	254(%36.0)	14(%18.4)		39(%19.6)	229(%39.3)	
Complex Stones	220(%85.6)	37(%14.4)		109(%42.4)	148(%57.6)	
Partial staghorn	57(%8.1)	5 (%6.6)		21(%10.6)	41(%7.0)	
Multi-caliceal	41(%5.8)	11 (%14.5)		24(%12.1)	28(%4.8)	
Pelvis + Lower Pole	89(%12.6)	8 (%10.5)		34(%17.1)	63(%10.8)	
Complete staghorn	33 (%4.7)	13 (%17.1)		30(%15.1)	16 (%2.7)	

*= Results of comparison beetween the simple-complex stones groups.

DISCUSSION

It is well-established that PNL procedure provides relatively higher stone-free rates which ranges over 90%, significant decreases in transfusion rate and lower morbidity. However, serious complications can also develop. The overall rate of complications ranges over 10% following PNL surgery in published data (8). Additionally, hemorrhage remains one of the most common and potential dangerous complication associated with PNL procedure (9). In a study Oner et al. reported an overall complication rate of 24.4% in 1750 PNL patients. Researchers documented hemorrhage requiring blood transfusion as the most frequent complication (12.6%) which classified as Grade 2 according to the Modified Clavien Classification. Furthermore; they reported 3 exitus due to severe urosepsis and 1 exitus due to severe bleeding. It was also noted that complication risk was significantly increased in patients with complex stones, multiple accesses and particularly patients with staghorn stones (p< 0,001) (10). Similarly in a study conducted with 671

patients who underwent PNL, Mousavi-Bahar et al. reported complication prevalence of 30.3%, moreover they documented renal parenchymal injury as the most frequent complication (15.4%), followed by peri-operative bleeding (6.3%). Researchers concluded that experienced hands may reduce complication rate in PNL procedure (11). In a multicenter cross-sectional study de la Rosette et al. reported an overall complication rate of 21.5% in 5,803 PNL patients. Researchers documented that the prevalence of grade I, II, III, IV and V complications based on modified Clavien system was 11.1%, 5.3%, 3.6%, 0.5% and 0.03%, respectively. Researchers also noted the most frequent minor complications as nephrostomy tube leakage, fever and major complications as injury to adjacent organs, bleeding (12). In accordance with these data, overall complication rate was 9.7% and the most frequent complication was severe hemorrhage (Grade 2) with a rate of 4.4% in our study. Furthermore, complication rate was statistically higher (14.4% vs. 7.4%) in cases with complex stones compared to the group with simple stones. On the other hand, overall blood transfusion rate was 15.1% during postoperative period. However, preoperative hemoglobin and hematocrit values of the patients who received blood transfusions were found to be statistically lower than the patients who didn't receive blood transfusions.

The European Association of Urology recommend PNL as gold standart procedure for renal stones>20 mm and lower pole stones>10 mm (5). In a meta-analysis Zhanget al. compared RIRS, PNL, and SWL techniques in 6 randomized and 8 non-randomized studies for treatment of lower pole renal stones. Researchers reported longer surgery time in RIRS and highest SFR in PNL procedure. Moreover, no statistical significant difference was noted according to the complication rates between the groups (13). Supportively in another meta-analysis Chen et al. concluded that PNL is a safe and feasible in treatment of staghorn stones compared to open surgery, furthermore they reported significantly lower complication rate, shorter surgery times, hospitalization times, less blood loss and blood transfusion in PNL group than open surgery (14). Ucer et al. reported significantly lower blood transfusion rates and hospitalization times in RIRS group (n=52) when compared to the PNL group (n=50) in patients with kidney stone 2-4 cm. On the other hand, researchers also highlighted that SFR was significantly higher in PNL group (15). However in a study ElSheemy et al highlighted that SFR is significantly affected by multiple stones or large stone burden during PNL technique (16). In another study consisting of 120 PNL patients, Karalar et al. reported overall prevalence of 74.1% (n=89) SFR. Additionally, researchers significantly associated stone-free status with stone localization, stone type and stone burden (p-values = $p<0.001$, $p<0.001$, and $p<0.01$, respectively) (17). Supportively, in a study conducted with 578 PNL procedure, Bayar et al. reported significantly higher (77% vs. 53%) SFR in cases with simple stones than complex stones ($p=0.005$). Researchers documented a significantly higher complication rate (19.5%) in group with complex staghorn stones ($p=0.006$). Moreover, researchers noted significantly higher mean duration of surgery and the number of access in patients with complex stones (18). Consistently in present study, PNL achieved a 74.6% overall SFR and SFR was found to be statistically lower in cases with complex stones (57.6% vs. 82.9%) than group with simple stones. Furthermore, significantly increased in mean number of accesses, surgery time, fluoroscopy time, nephrostomy removal time and hospitalization time documented in cases with complex stones. Since the patients included in this study were in all age groups and a rigid nephroscope was used, our findings were limited compared to studies that additionally used micro-perc and flexible nephroscope. Different findings may be obtained with selected patients group with similar age range. However we obtained markable and valuable findings particularly with our large sample group.

In conclusion, our findings clearly demonstrated that PNL achieved a higher success rate and lower complication risk in patients with simple stones compared to the group with complex stones. Moreover, PNL is significantly associated with shorter operation duration and hospitalization in cases with simple stones. Furthermore, PNL provided relatively higher overall SFR and lower complication rates in our large sample group compared to the published data.

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Conflict of Interest: Authors declare that they have no conflict of interest.

Informed Consent: Informed consent was obtained from all individual participants included in the study.

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