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Parenchymal Thickness: Does It Have an Impact on Outcomes of Percutaneous Nephrolithotomy?

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Key Words
Renal parenchyma · Renal calculi · Percutaneous nephrolithotomy · Renal access · Outcome

Abstract
Objective: To evaluate whether renal parenchymal thickness (RPT) has an effect on the outcomes of percutaneous nephrolithotomy (PNL). ***Methods:*** We performed a retrospective analysis of 144 patients with lower pole and/or renal pelvic stones who underwent PNL. The relationship between RPT and peri- and postoperative measures was evaluated. ***Results:*** The average age was 45.94 ± 14.47 (15–76) years. The mean BMI was calculated as 27.47 ± 4.73 (16.9–44.9) kg/m^2. The mean stone burden was 293 ± 126 (150–800 mm^2). The mean RPT was measured as 17.33 ± 5.32 (6–35) mm. No correlation was detected between the RPT and the operation or fluoroscopy times or the duration of hospitalization ($p = 0.63$, 0.52, 0.08, respectively). The mean drop in hemoglobin level was 1.45 ± 1.25 (0–9) g/dl. A negative correlation was detected between hemoglobin drop and RPT ($p = 0.01$, $r = -0.23$). However, the RPT was similar in patients who did or did not require a blood transfusion ($p = 0.09$). The RPT was found to have no impact on success rate ($p = 0.4$). ***Conclusion:*** The postoperative hemoglobin drop increases in parallel with the increase in RPT. However, no relationship was detected between the RPT and blood transfusion, overall success rate or any other perioperative parameters.

Introduction

After the description of percutaneous renal access by Goodwin et al. [1] in 1955, percutaneous nephrolithotomy (PNL) was first introduced by Fernström and Johansson [2] in 1976. Today, PNL has been considered a gold standard procedure for the treatment of patients with renal stones >2 cm in size [3]. The rate of success for PNL has increased due to technological refinements and increased surgical experience.

The procedure is mainly performed through a gate (percutaneous renal access) that allows the surgeon to access the collecting system of the kidney from the skin. Although patient- and stone-related factors such as age, body mass index (BMI), stone type and size may affect the success and complication rates of the PNL, these factors are more directly related to the adequacy of percutaneous renal access [4].

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The creation of percutaneous renal access involves the following steps: puncture to the proper calyx, dilation of the tract and access sheath insertion. The proper puncture is defined as one made in a straight line traversing the shortest distance from the skin to the infundibulum [5]. The renal parenchyma that includes the vascular structure is generally damaged during the creation of an access point. Renal parenchymal thickness (RPT) was found to be predictive of the amount of blood loss during PNL [6]. However, no study has focused on the effects of RPT on procedure outcomes.

In this study, we aimed to evaluate whether RPT has an effect on the outcomes of the PNL procedure.

Subjects and Methods

We performed a retrospective analysis of 144 patients with lower pole and/or renal pelvic stones who underwent PNL with a lower pole posterior calyceal access by two experienced urology teams at two referral hospitals in Turkey between September 2010 and March 2012. To eliminate the possible biases related to access number and location, stone size and type, the patients with complex renal stones requiring multiple calyceal accesses were excluded from the study.

All patients were evaluated preoperatively with respect to renal function, hemostasis, and urinary infection. The parenchymal thickness of lower pole (mm) was measured by the axial plane of CT. Stone burden was assessed according to the European Association of Urology guidelines [3]. Hydronephrosis was graded as either nil/mild or moderate/severe using ultrasonographic criteria. The estimated glomerular filtration rate (eGFR) was calculated by using the Cockroft-Gault formula for all patients [7].

After the insertion of a ureteral catheter in the lithotomy position, access to the posterior calyceal calyx was achieved intraoperatively with the aid of C-arm fluoroscopy using an 18-gauge access needle with the patient in the prone position as previously described [8]. Tract dilation was accomplished using a high-pressure balloon dilator (Nephromax™; Boston Scientific) (n = 79) or Amplatz dilators (n = 65′′). Fragmentation of the stone burden was performed using a pneumatic or ultrasonic lithotripter (Swiss Lithoclast®; EMS). The stone fragments were removed using forceps. Flexible nephroscopy was performed at the end of the procedure in patients with suspected residual stones. Holmium-yttrium-aluminum-garnet laser lithotripsy was preferred if residual fragments were detected deep in the calyces. In the majority of cases, a 14-Fr nephrostomy tube was placed inside the renal pelvis or the involved calyx upon conclusion of the procedure. The tubeless procedure was indicated in patients with mild or moderate stone burden, no residual stones, or no perioperative complications, depending on the surgeon's preference.

Plain radiography of the kidneys, ureters, and bladder was obtained on postoperative day 1. On postoperative day 2, the nephrostomy tube was removed from patients who were rendered stone-free and from those with clinically insignificant residual fragments (CIRFs). All patients were evaluated with a spiral CT after 3 months had passed since the time of the operation. The results were classified as stone-free, CIRFs, and unsuccessful (residual stones). CIRFs were defined as ≤4 mm, non-obstructing, non-infectious, or asymptomatic residual fragments [9]. Complications were classified according to the Clavien grading system [10, 11].

Statistical Analysis

Data were analyzed with SPSS 16.0 for Windows (SPSS, USA). The results are presented as the mean ± SD. The relationship between parenchymal thickness (mm) and patient (gender, age, hydronephrosis, previous renal surgery) as well as procedure-related factors (dilation type, success, complication rate and the need for transfusion) were analyzed by Mann-Whitney U tests. The impact of parenchymal thickness on operation and fluoroscopic screening times as well as the drop in the hemoglobin level and eGFR was evaluated using Spearman's correlation tests.

Results

A total of 144 patients were enrolled in the study. The male/female ratio of patients was 84/60. The average age and BMI were calculated as 45.9 ± 14.47 years (range 15–76) and 27.47 ± 4.73 kg/m^2 (range 16.93–44.9), respectively. The mean stone size was 293 ± 126 mm^2 (range 150–800). The mean RPT was measured as 17.33 ± 5.32 mm (range 6–35) (table 1). The RPT was similar in patients stratified according to sex, age (≤40 and >40 years) and BMI (≤30 and >30 kg/m^2) ($p = 0.64$, $p = 0.63$, $p = 0.28$, respectively) (table 2). A history of ipsilateral renal open surgery was noted for 38 patients. No significant difference was found in patients with or without a history of renal surgery in terms of RPT (18.1 ± 5.3 vs. 17.1 ± 4.5 mm, $p = 0.12$). The parenchyma was found to be slightly thinner in patients with moderate or severe hydronephrosis compared to patients with nil or mild hydronephrosis (17.1 ± 5.4 vs. 17.4 ± 5.3, $p = 0.69$) (table 3). No correlation was found between eGFR and the parenchymal thickness ($p = 0.7$, $r = 0.03$).

The mean operation and fluoroscopic screening times were 57.34 ± 25 min (range 14–180) and 4.61 ± 2.58 min (range 0.5–15), respectively. The mean duration of hospitalization was 2.41 ± 1.34 days (range 1–11). No correlation was detected between RPT and operation or fluoroscopic screening times or the duration of hospitalization ($p = 0.63$, $p = 0.52$, $p = 0.08$, respectively). In addition it is found that the tract dilation method did not significantly affect the operation time ($p = 0.12$), hemoglobin drop ($p = 0.74$) and the success of the procedure ($p = 0.55$) (table 4).

The mean drop in the postoperative hemoglobin level was 1.45 ± 1.25 g/dl (range 0–9). A negative correlation was detected between the hemoglobin drop and RPT

Table 1. Demographic values of the patients

Number of patients	144
Male/female	84/60
Mean age, years	45.94±14.47 (15–76)
Mean BMI, kg/m^2	27.47±4.73 (16.93–40.86)
Mean stone burden, mm	293±126 (150–800)
Mean thickness of the renal parenchyma, mm	17.33±5.32 (6–35)
Previous ipsilateral renal surgery	38
Grade of hydronephrosis	
Nil or mild	71
Moderate or severe	73

Table 2. Peri- and postoperative parameters

Hemoglobin drop, g/dl	1.45±1.25 (0–9)
Operation time, min	57.34±25 (14–180)
Fluoroscopic screening time, min	4.61±2.58 (0.5–15)
Mean hospitalization, days	2.41±1.34 (1–11)
Stone-free status	
Stone-free	114 (79.2%)
CIRFs	12 (8%)
Rest	18 (12.5%)
Additional treatments	
SWL	7
PNL	3
URS	2
Complications	22 (15.3%)
Clavien grade 1	
Postoperative fever	4
Clavien grade 2	
Bleeding requiring transfusion	11 (7.5%)
Urinary tract infection	2
Clavien grade 3A	
Prolonged urine leakage managed by ureteral stent placement	3
Pelvicalyceal perforation treated with prolonged nephrostomy tube	1
Clavien grade 4	
Urosepsis	1

Table 3. Distribution of the patients according to the demographic and operative parameters and the mean parenchymal thickness values

Parameter	Parenchymal thickness, mm	p
Gender		0.64
Male	17.1±5.5	
Female	17.6±5.1	
Age, years		0.63
≤40	17.4±6.7	
>40	17.2±4.4	
BMI, kg/m^2		0.28
≤30	17.4±5.1	
>30	16.8±6.4	
Previous open surgery		0.12
(–)	18.1±5.3	
(+)	17.1±4.5	
Hydronephrosis		0.69
Nil or mild	17.4±5.3	
Moderate or severe	17.1±5.4	
Bleeding requiring transfusion		0.09
(–)	17.1±5.4	
(+)	19.4±3.3	
Success status		0.40
Successful	17.5±5.4	
Rest	16.1±4.5	

Table 4. Comparison of outcomes of PNL according to the dilation methods

	Balloon dilation	Amplatz dilation	p
Number of patients	79	65	
Parenchymal thickness, mm	17.38±4.7	17.22±6	0.75
Operation time, min	53.43±21.6	62.2±28.1	0.12
Hemoglobin drop, g/dl	1.49±1.5	1.4±0.9	0.74
Success, %			0.55
Stone-free	75.9	83.1	
Rest	10.2	6.1	
CIRFs	13.9	10.8	

(p = 0.01, r = –0.23). A postoperative blood transfusion (Clavien grade 2 complication) was required in 11 patients (7.5%). However, the parenchymal thickness was similar in patients who either did or did not require a blood transfusion (p = 0.09).

A total of 22 (15.3%) postoperative complications were observed. The double-J stent was inserted in 3 patients with urine leakage from the tract more than 24 h after the removal of the nephrostomy tube (Clavien grade 3a complication) [12]. Six patients had fever on the first day after PNL. The fever resolved spontaneously in 4 patients (Clavien grade 1 complication). The remaining 2 patients were managed with antibiotics because of the positive urine culture (Clavien grade 2 complication). In addition, pelvicalyceal system perforation was treated by prolonged nephrostomy tube in 1 patient (Clavien grade 3a complication) As a major complication, urosepsis was observed in 1 patient (Clavien grade 4 complication) (table 2).

An overall success rate of 87.5% (126/144), including CIRFs in 8.3% (12/144), was achieved. Repeated PNL, shock-wave lithotripsy and ureteroscopy were performed as axillary treatment modalities in 3, 7, and 2 patients, respectively. No significant difference in terms of RPT was present in patients classified according to the success of the PNL procedure (17.5 ± 5.4 vs. 16.1 ± 4.5 mm, p = 0.4).

Discussion

The RPT is accepted as an indicator of relative renal function in chronic obstructive renal disease and an independent variable to predict the recoverability of renal function after resolution of the obstruction [13–17]. The size and thickness of the kidney are affected by various congenital and acquired conditions and age. The main factor affecting the renal parenchyma and a frequent cause of renal failure in the pediatric population is urinary tract obstruction [18]. An experimental study showed that apoptosis is associated with a loss of renal parenchyma that lasts for 1 month after ureteral ligation [19]. Urinary stone disease is the most common reason for urinary tract obstruction. Therefore, RPT decreases in patients with partial or complete urinary obstruction. The presence of an infection in an obstructed system contributes to the deterioration of renal function and to a decrease in the RPT.

Percutaneous renal access results in a high stone-free rate and low morbidity after the PNL procedure [20–22]. Stone disintegration and removal of the stone fragments are performed using the nephroscope, which is inserted in the collecting system through the gate-renal access. The renal access route transverses the shortest straight axis from skin through the renal parenchyma and papilla of the desired calyx into the pelvicalyceal system. The renal parenchyma is damaged during the creation of the tract.

The main factors affecting the outcomes of the PNL procedure are the experience of the surgeon [23], stone complexity, access location [24] and multiplicity- and patient-related factors (BMI, etc.). To exclude the effects of all these factors, patients with stones of similar sizes who had undergone PNL by two experienced urological teams with a single puncture directed to the posterior lower calyx were enrolled in the study.

Bleeding is one of the most common complications of PNL with an incidence varying between 0.8 and 45% [25–27]. Hypertension and diabetes mellitus are two patient-related independent predictive factors affecting bleeding risk [6, 28, 29]. The authors exploring the factors affecting blood loss during PNL concluded that complex renal stones requiring multiple renal tracts are associated with high transfusion rates [6, 26, 28, 30]. Bleeding generally occurs while creating the access route (e.g. renal puncture, dilation, advancement of the sheath into the renal parenchyma) [31]. The effect of dilation technique on hemorrhagic complications is regarded as confusion that different results are reported in the literature. Although some authors [32–35] reported that the telescopic, balloon, and one-shot dilation had similar hematologic safety profiles, others [36, 37] reported lower transfusion rates for balloon dilation. In the present study, the patients were stratified according to the dilation technique. It has been found that the dilation method did not significantly affect the perioperative outcomes such as operation time, success and hemoglobin drop (table 4).

With advances in endoscopes and lithotripsy devices, single-access PNL has been able to improve the morbidity and complication with flexible instrumentation or the use of a mini-PNL [38, 39]. It has been postulated that achieving renal access to a hydronephrotic kidney with thin renal parenchyma is associated with less blood loss [40]. Similarly, an increase in the thickness and size of a solitary kidney as a physiological response is identified a significant risk factor for bleeding [41–43]. In the literature, there is only one study evaluating the effect of the renal parenchyma on blood loss during PNL. In that study, Kukreja et al. [6] found that the hemoglobin drop was higher in patients with parenchymal thickness >10 mm than <10 mm (p = 0.05). In the present study, the mean parenchymal thickness was measured as 17.33 ± 5.2 mm. A negative correlation was detected between RPT and hemoglobin drop (p = 0.01, r = –0.23). However, no correlation was detected between bleeding requiring blood transfusion and RPT (p = 0.09). Blood transfusion was required in 11 patients (7.5%). Additional intervention was not necessary for any of the patients.

Although achieving renal access to hydronephrotic kidneys with thin renal parenchyma is easier than in nondilated kidneys with thick renal parenchyma, the maintenance of the tract can be more difficult in hydronephrotic kidneys. Moreover, extravasation of the contrast medium, irrigation fluid and stone fragments near the access sheath can be observed. The thick renal parenchyma surrounding the access sheath prevents extravasation of the

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urine and irrigation fluid. In addition, we hypothesize that closure of the renal tract could be faster in patients with thick renal parenchyma with a good blood supply. Although prolonged urine leakage from the access tract treated with ureteral stent insertion was observed in 3 patients as a complication in the present study, no correlation was found between RP thickness and overall complication rate.

The renal parenchyma could be damaged during fragmentation of the stone. While using a pneumatic device as a lithotripter, the collecting system surrounded by the thin renal parenchyma could be perforated in inexperienced hands. Perforation of the system leads to the extravasation of irrigation fluid and stone fragments, which in turn leads to a decrease in the intrarenal pressure and blurred vision. To prevent parenchymal perforation, some measures can be applied such as the following: the use of an ultrasonic lithotripter with suction or pneumatic lithotripter with a single pulse and low pressure levels. In the present study, perforation of the pelvicalyceal system was observed in 1 patient and treated with prolonged nephrostomy tube placement.

The retrospective nature and small number of individuals included in the study can be considered as limitation factors. In addition, the parenchymal thickness of the punctured calyx-posterior lower pole was used as a parameter in the present study. The lack of correlation between RPT and eGFR might be related to this reason in this study [17]. However, despite these limitations, considering the lack of any study evaluating the effect of RP thickness on the outcomes of PNL, this study is a valuable contribution to the existing data.

Conclusion

This is the first study evaluating the RP thickness on outcomes of PNL. The results of the study show that blood loss during PNL increases in parallel with the increase in RPT, which is accepted as an indicator of kidney viability and functionality. However, no relationship was detected between RPT and blood transfusion, overall success or complication rate or any other operative parameter.

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