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Effects of Parenchymal Thickness and Stone Density Values on Percutaneous Nephrolithotomy Outcomes

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Background: It is unclear whether parenchymal thickness (PT), in combination with stone density measured by Hounsfield Units (HU), affects stone-free rates after PCNL. The aim of the present study was to investigate the relationship between PT in combination with stone density values and the outcomes of PCNL.

Material/Methods: From 2009 to 2014, data from 216 PCNL patients were prospectively analyzed. In total, 120 patients were included in the study. Using NCCT images, stone burden, stone localization, stone density as HU values, PT, and operative-postoperative parameters were recorded.

Results: Stone localization, stone type, stone burden, and presence of hydronephrosis were statistically significant factors affecting stone-free status ($p<0.001$, $p<0.001$, $p<0.01$, and $p<0.01$, respectively). The stone-free rate in patients with thicker renal parenchyma was higher than in patients with lower parenchymal thickness ($p<0.01$). No correlation was detected between stone density and success rate ($p>0.05$). Drop in Hb (%) was only correlated with parenchymal thickness ($p<0.01$). In univariate analyses, factors that affected blood transfusion requirement were PT, BMI, and operative times ($p<0.01$, $p<0.05$, and $p<0.05$, respectively).

Conclusions: Stone location, stone burden, and presence of hydronephrosis detected with NCCT were factors affecting PCNL outcome. Stone density values did not correlate with the rate of bleeding or success of PCNL. PT measured by NCCT may predict bleeding and may guide surgeons in determining preoperative blood requirements. The outcome of PCNL appeared to be better in patients with thicker renal parenchyma and should be taken into consideration in the clinical evaluation of patients undergoing PCNL.

MeSH Keywords: Kidney Calculi • Nephrostomy, Percutaneous • Tomography, X-Ray Computed

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Background

Percutaneous nephrolithotomy (PCNL) is a well-established and safe procedure for the management of renal stones [1–3]. The outcome of the procedure depends on a variety of factors, including operative technique, body mass index (BMI), number of comorbidities, renal collecting system anatomy, initial stone burden and localization, number of accesses, and history of previous renal surgery [4–6]. Currently, non-contrast computed tomography (NCCT) has an important place in the preoperative radiologic evaluation of patients with renal stones [7,8]. With the aid of NCCT, stone density measured as Hounsfield units (HU) and the thickness of the renal parenchyma can be easily detected [9]. Renal parenchymal thickness (PT) and stone density are other possible factors that may affect the outcome of PCNL [10].

The percutaneous renal access route to a kidney stone comprises skin, subcutaneous tissue, visceral adipose tissue, perirenal space, and renal parenchyma. Because the renal parenchyma is traversed while creating an access, this may theoretically cause tissue damage and consequently bleeding, which may possibly affect the surgical outcome. Increased stone density was demonstrated to be associated with low stone-free rates, and fragmenting harder stones may also cause collecting system damage [11]. The results of previous studies on the effects of parenchymal thickness on PCNL outcomes revealed contradictory results [10,12–14]. It is unclear whether parenchymal thickness, in combination with stone density measured by Hounsfield units, affects stone-free rates after PCNL.

The aim of the present study was to investigate the relationship between PT in combination with stone density values and the outcomes of PCNL.

Material and Methods

From 2009 to 2014, data from 216 PCNL patients were prospectively analyzed. Of these, patients lost to follow-up, those with missing NCCT or with complex stones requiring multiple accesses were excluded from the study. The data of the remaining 120 procedures were analyzed regarding the preoperative factors, postoperative factors and the outcomes of PCNL. The procedure of the current study was approved by the local ethics committee of our institution and informed consent was obtained from all patients.

All patients were evaluated before the operation by whole blood count, serum biochemistry, coagulation tests, urinalysis and urine culture, if necessary. Radiologic examinations, including intravenous urography (IVU) and NCCT, were used to determine the kidney anatomy, stone localization and burden, and renal PT. Images were evaluated by a radiologist and coronal and/or sagittal reformatted CT images were used to supplement the axial images, when necessary. Measurements of attenuation values in Hounsfield units were performed using bone window settings with magnification. Parenchymal thickness (mm) of the kidney was measured at the planned calyx of puncture using soft tissue window settings in the axial images on NCCT (Figure 1). The stone burden was measured as the product of the 2 dimensions on plain radiographs. The sum of the largest diameters of all stones was obtained by addition of the maximal length of each stone. Stone surface areas were estimated using an arithmetic calculation formula [15]. Preoperative parameters of the patients, including age, sex, body mass index (BMI), previous kidney surgery, and history of extracorporeal shock wave lithotripsy (SWL) were recorded. Using the NCCT images, stone localization, stone burden, and density of the stones as HU values were also recorded.

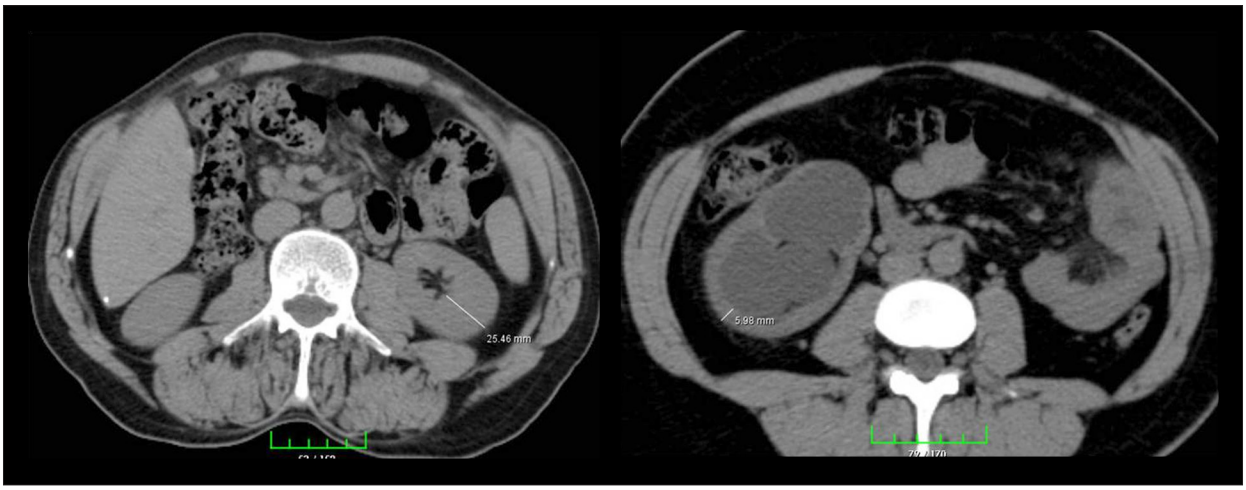

Figure 1. Parenchymal thickness measurement through the lower pole of the kidney in 2 different patients.

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All PCNL procedures were done in standard aseptic manner and in the prone position under general anesthesia. Tract dilatation was performed with Amplatz dilators in all patients. An 18F nephrostomy catheter was routinely left in place after the operations. The nephrostomy catheter was withdrawn on the second or third postoperative day, unless a complication occurred requiring an extended period of drainage. Success was defined as stone-free status or residual fragments smaller than 4 mm. Operative time, fluoroscopy time, intraoperative complications, and duration of nephrostomy and hospitalization were recorded. The Clavien classification system was used for postoperative complications [16]. Serum examinations were performed during the first postoperative day in all cases. Blood loss was determined with the formula: (percent of hemoglobin (Hb) drop): (preoperative Hb – postoperative Hb)/preoperative Hb ×100. Additionally, transfused blood units were recorded. Because 1 unit of blood transfusion increases the Hb level by 1 g/dl, this increase after transfusion was removed from postoperative Hb levels in the formula.

The aforementioned patient- and stone-related factors, as well as renal PT and stone density values, were compared with procedure outcome. The independent effects of PT, stone density, and stone burden on success of the surgery were evaluated using a multivariate logistic regression model. The Statistical Package for Social Sciences, version 15.0 (SPSS, Chicago, Illinois, USA) was used for statistical analysis. To determine the normality of distributions, variables were investigated using visual (histograms and probability plots) and analytical methods (Kolmogorov-Smirnov test). Values are given as mean ± standard deviation. The *t* test was used for group comparisons and the chi-square test was used for variables between categorical data. The Mann-Whitney U test was used to compare variables without normal distribution between the 2 groups and $p<0.05$ was accepted as the significance level.

Results

Data from 216 PCNL patients were prospectively analyzed. Of these, patients lost to follow-up, those with missing NCCT, or with complex stones requiring multiple accesses were excluded from the study and the data of the remaining 120 procedures were included. Demographic data of the patients and pre-/postoperative findings according to stone-free status versus residual stones are summarized in Table 1. Stone localization, stone type, stone burden, and presence of hydronephrosis were statistically significant factors affecting stone-free status ($p<0.001$, $p<0.001$, $p<0.01$, and $p<0.01$, respectively). Additionally, PT was also a significant factor affecting the success rate ($p<0.01$). The stone-free rate of patients with thicker renal parenchyma was higher than in patients with lower parenchymal thickness. No correlation was detected between stone density and success rate ($p>0.05$). Overall blood transfusion rate was 16.6% (n=20). In univariate analyses, factors that affected blood transfusion requirement were PT, BMI, and operative times ($p<0.01$, $p<0.05$, and $p<0.05$, respectively). Stone localization, burden, and density were not correlated with blood transfusion requirement ($p>0.05$, $p>0.05$, and $p>0.05$, respectively). Drop in Hb (%) was only correlated with parenchymal thickness ($p<0.01$).

The median PT value of the patients was 14.5 mm. Patients were evaluated according to PT<14.5 mm (Group 1) and PT>14.5mm (Group 2). Drop in Hb (%) and stone-free rates were lower in group 1 ($p<0.01$ and $p<0.01$, respectively). Additionally, stone burden was higher in group 1 ($p<0.01$) (Table 2).

Forward multivariate regression analysis revealed that stone burden and PT were significant predictors of stone-free outcome ($p<0.01$, $p<0.05$, respectively) (Table 3).

In the present series, the mean HU value was 1139.71±295.03. The CROES Percutaneous Nephrolithotomy Study Group has stated that the optimal stone density for stone-free outcome is 1250 HU [4]. Therefore, patients were also evaluated according to stone HU values and divided into 2 groups: group 1 patients with <1250 and group 2 patients with HU>1250. Only fluoroscopy time was higher in group 1 ($p<0.05$). There were no statistically significant differences in other parameters (Table 4).

Discussion

Stone location, size, and hydronephrosis were defined as significant factors affecting PCNL surgery success in many studies [11,17–19]. Similarly, we found that stone location, stone burden, and presence of hydronephrosis affected the success of PCNL surgery.

In the current literature, stone density has been discussed only in terms of visibility. To the best of our knowledge, there is no study in the literature that evaluates the effects of stone density and PT together on PCNL [4,20]. The aim of this study was to investigate the effects of stone density and PT on PCNL surgery.

Gucuk and colleagues have suggested that PCNL is a more efficient method for stones with higher HU values. In ROC analysis, they found the cutoff value for HU to be 677.5. They suggested that when the HU value was under the cutoff, the residual stone increased by 2.65. They explained this efficiency by the opacity and visibility of the stones with higher HU values [11]. In the study of Anastasiadis and colleagues, patients who had undergone PCNL were divided into 2 groups: a low stone density group (<1000 HU) and a high stone density group (>1000HU). They observed that the stone-free rate was higher in the high stone density group, but this was not

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Table 1. Demographic and surgical characteristics of patients.

	Stone-free (n=89)	Residual Stones (n=31)	p value
Age	42.7±13.3	44.3±12.3	>0.05
Sex (n)			
Male	49 (55.1%)	19 (61.3%)	>0.05
Female	40 (44.9%)	12 (38.7%)	
BMI (kg/m^2)	26.9±3.06	27±4.37	>0.05
BMI			
x<25	18 (20.2%)	8 (25.8%)	>0.05
25≤x<30	58 (65.1%)	16 (51.6%)	
30≤x	13 (14.6%)	7 (22.5%)	
History of SWL (+)	18 (20.2%)	5 (16.1%)	>0.05
History of SWL (–)	71 (79.7%)	26 (83.9%)	
History of renal surgery (+)	16 (17.9%)	10 (32.3%)	>0.05
History of renal surgery (–)	73 (82.0%)	21 (67.7%)	
Laterality			
Left	36 (40.4%)	15 (48.4%)	>0.05
Right	53 (59.6%)	16 (51.6%)	
Stone localization			
Pelvic	59 (66.3%)	6 (19.4%)	**<0.001**
Isolated caliceal	12 (13.5%)	2 (6.5%)	
Multiple + Staghorn	18 (20.2%)	23 (74.2%)	
Stone type			
Staghorn	18 (20.2%)	23 (74.2%)	**<0.001**
Non-staghorn	71 (79.8%)	8 (25.8%)	
Stone Burden	388.01±278.37	998.74±978.83	**<0.01**
Hydronephrosis (+)	43 (48.3%)	23 (74.2%)	**<0.01**
Hydronephrosis (–)	46 (51.6%)	8 (25.8%)	
Stone density (HU)	1127.72±301.93	1173.35±276.65	>0.05
Parenchymal thickness (mm)	15.56±5.46	11.35±5.97	**<0.01**
Operative time (min)	111.97±40.68	143.26±71.22	**<0.01**
Fluoroscopy time (min)	6.51±4.34	8.57±4.96	**<0.05**
Transfusion (+)	15 (16.8%)	5 (16.1%)	>0.05
Transfusion (–)	74 (83.1%)	26 (83.8%)	
Drop in hemoglobin (%)	1.97±1.08	1.80±0.76	>0.05
Hospitalization (days)	3.57±1.42	3.68±1.13	>0.05

statistically significant (p>0.05). They suggested that the presence of low-density and very high-density stones is associated with lower stone-free rates in PCNL surgery. They found the optimal stone density for stone-free outcome was approximately 1250 HU and suggested that values above or below this density are associated with less successful PCNL surgery and increase the probability of retreatment [4].

In our study, we found no correlation between HU values and stone-free status. The mean HU values were approximately similar in stone-free patients, patients with residual stones, and in patients overall (1127±301 and 1173±276, 1139.71±295.03, respectively). This was not statistically significant, as in the study of Anastasiadis (p>0.05). We also evaluated patients according to HU<1250 and HU>1250 and found similar stone-free rates (74% and 73.5%, respectively). Additionally, our patients' stone densities were higher than in the previous studies and all stones were visible in the scope, indicating that the stones are hard in our region.

Gucuk et al. observed a positive correlation between HU values and hematocrit decrease [11]. In contrast to this study,

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Table 2. Operative and postoperative data of patients according to parenchymal thickness.

	Group 1	Group 2	p
n	52	68	
PT (mm)	<14.5	>14.5	
Stone burden (mm²)	737.1±111.6	399.4±41.1	**<0.01**
Operative time (min)	125.7±7.1	117.6±6.2	>0.05
Fluoroscopy time (min)	7.5±0.6	6.6±0.5	>0.05
Drop in Hb (%)	11.2±0.7	15.0±0.8	**<0.01**
Hospitalization (days)	3.6±0.2	3.5±0.1	>0.05
Stone-free	31 (59.6%)	58 (85%)	**<0.01**

Table 3. The independent effects of parenchymal thickness and stone burden on the outcome of PCNL using multivariate logistic regression model.

	B	S.E.	Exp (B)	p
Parenchymal thickness	–0.102	0.044	0.903	<0.05
Stone burden	0.002	0.001	1.002	<0.01
Constant	–0.723	0.698	0.485	>0.05

Table 4. Operative and postoperative data of groups according to HU values.

	Group 1 HU <1250 (n=67)	Group 2 HU >1250 (n=53)	p value
Stone burden (mm²)	471.1±437.6	640.1±767.7	>0.05
Operative time (min)	113.6±37.3	130.6±63.3	>0.05
Fluoroscopy time (min)	7.8±4.7	5.9±4.0	**<0.05**
Drop in Hb (%)	13.3±6.7	13.6±6.8	>0.05
Hospitalization (days)	3.5±1.2	3.6±1.4	>0.05
Stone-free	50 (74%)	39 (73.5%)	>0.05

Anastasiadis et al. reported that blood transfusion rates and operative time were greater in patients with stone density less than 1000 HU [4]. In our study, we found no correlation between HU values and bleeding, perhaps due to the similarity of the HU values of the stones. We also could not determine a cut-off value with ROC analysis. Operative time and hospitalization were not significantly different in our patients with HU <1250 U *vs.* HU >1250 U.

Moreover, the association between renal PT and efficacy and safety of PCNL has not been extensively investigated. It is suggested that thickness of the renal parenchyma may be an important factor that affects bleeding and success in PCNL. There are only a few reports about the effect of PT on percutaneous nephrolithotomy [10,12]. Tepeler et al. observed no relationship between PT and success rate. In our study, the stone-free rate was higher in patients with thicker parenchyma (p<0.01). Although PCNL seems to be more successful in patients with thicker parenchyma, this situation can be explained by these patients having a lower stone burden (p<0.01). Additionally, we observed that patients with staghorn stones have thinner parenchyma (p=0.05), which can easily be explained by considering that the most important factors that affect the success of this surgery are related to the presence of staghorn stone and/or high stone burden.

Tepeler et al. observed that postoperative hemoglobin drop increases in parallel with the increase in PT, but they did not

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find any correlation between blood transfusion and PT [12]. Kukreja et al. reported that increased renal PT was associated with significantly increased blood loss [10]. In a more recent study, no relationship was detected between PT and bleeding [13], but the tracts were dilated with Amplatz or balloon dilators. Using 2 different dilators may be a disadvantage since they also affect bleeding. In our study, the drop in Hb (%) was only correlated with PT ($p<0.01$). Additionally, PT was thicker in patients who required blood transfusion ($p<0.001$).

Conclusions

Stone location, stone burden, and presence of hydronephrosis detected with NCCT are the factors affecting PCNL outcome. Stone density values do not correlate with the rate of bleeding or success in PCNL. Parenchymal thickness measured by NCCT may predict bleeding and may guide surgeons in determining preoperative blood requirements. In our series, the stone burden of patients with thicker renal parenchyma was less than in patients with thinner parenchyma. Therefore, the outcome of PCNL appears to be better in patients with thicker renal parenchyma; this should be taken into consideration in the clinical evaluation of patients undergoing PCNL.

Statements

Funding: No funding was received for this study.

Conflict of interest: The authors declare that they have no conflict of interest.

Ethics approval: All procedures performed in studies involving human participants were in accordance with the ethics standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethics standards.

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

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