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Stones hounsfield unit value and predictors of urinary leakage after PCNL

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Abstract

Background: To evaluate the predictive factors of urinary leakage (UL) following percutaneous nephrolithotomy (PNL) and to investigate the relationship between Hounsfield unit (HU) of stone and UL.

Methods: We retrospectively reviewed the data of 728 patients who underwent PNL between January 2012 and January 2017. In total, 396 patients were eligible for the study. Patient demographics, renal factors, stone properties and operative details were collected. The association between UL and these variables were assessed by univariate and multivariate analysis.

Results: There was no statistically significant correlation considering age, body mass index and the presence of hypertension. The presence of diabetes mellitus (DM) was significantly correlated with UL ($p < 0.001$). Kidney related factors such as parenchymal thickness, hydronephrosis grade (HN), previous stone treatment, and stone related factors, such as stone surface area, stone burden, stone localization and HU value of stone, were found to affect UL status significantly ($p < 0.001$). Operation time, fluoroscopy time, treatment outcome, j stent use, percutenous nephrostomy (PCN) catheter stay time and the hospitalization time also had significant effect on UL ($p < 0.001$). Multivariable logistic analysis showed that presence of DM, parenchymal thickness, HU values, HN, operation time, j stent use, and PCN catheter stay time are independently related with UL following PCNL. Moreover, we determined a HU cut-off value of 933 with ROC analysis, which demostrated 84.9% sensitivity and 67.1% specificity for predicting UL.

Conclusion: This study has shown that we are more likely to encounter postoperative UL in stones with higher HU values. Therefore, we suggest clinicians to inform patients with this type of kidney stones about the probable complication of UL.

Keywords: Urinary leakage, Percutaneous nephrolithotomy, Predicitive factors, Stone density, Stone Hounsfield unit

1 Background

Percutaneous nephrolithotomy (PCNL) is considered as gold standard first line surgical technique for treatment of kidney stones over 2 cm by European Association of Urology Guidelines [1]. It is a well-known and safe method with high success rates since the first reported study in 1976 by Fernastom and Johansson [2]. In the light of technological developments, such as miniaturization of instruments, complication rates are decreased over years. However urinary leakage through the nephrostomy tract after nephrostomy removal is still a main concern. Previous studies demonstrated that some predicting factors including stone size, stone burden, stone location, body mass index (BMI), collecting system anatomy and history of renal surgery may have an effect on urinary leakage (UL) after PCNL [3, 4].

Regarding the radiological evaluation of urinary stone patients, non-contrast computed tomography (NCCT) has an important role. NCCT has the highest sensitivity and specificity to detect urinary stones [5–7]. Therefore,

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NCCT is the most preferable radiological imaging method for the diagnosis of urinary stones. Hounsfield Unit (HU) value particularly, has an important role for diagnostic evaluation. It has been reported that the HU value determined by the NCCT is associated with mineral composition and the success rate of surgical methods. To the best of our knowledge, there is no study in the English literature that evaluates the predictive role of HU value on urinary leakage (UL) after PCNL.

Our aim in this study is to specify the predictive factors of urinary leakage following nephrostomy removal and to evaluate the effect of HU on UL status.

2 Methods

We retrospectively reviewed the data of 728 patients who underwent PCNL between January 2012 and January 2017. Patients with missing NCCT before procedure, complex stones which require multiple accesses, uncontrolled diabetes mellitus (blood glucose level > 200 mg/dL during the hospitalization period) and uncontrolled hipertension were excluded from the study. The data of remaining 396 patients were analyzed. Preoperative characteristics including age, sex, BMI, presence of diabetes mellitus (DM) and hypertension (HT) were recorded. DM was assigned for those having the diagnosis of type 2 disease at the time of surgery. The DM diagnosis was based on preoperative fasting glucose levels > 126 mg/dL [8] and receiving current medical therapy for DM, such as oral antidiabetics or insulin. Owing to inadequate data for glycated hemoglobin (HbA_{1c}) levels, we did not include this parameter. Stone surface area, stone burden, stone localization, parenchymal thickness (PT), HU values, existence of hydronephrosis, previous treatment, operation period, duration of the fluoroscopy, treatment outcome, j stent use, percutaneous catheter stay time, hospitalization period and the presence of UL were noted. These factors were compared according to the presence or absence of UL. Following the removal of the nephrostomy after PNL surgery, UL may occur in some of the cases from the nephrostomy tract. In this study, patients whose surgical incision become so wet that it needs sponge changes after the 6th hour of nephrostomy extraction were defined as UL.

2.1 Surgical technique

Prior to surgery, serum biochemistry, whole blood count, bleeding time, urine analysis and urine culture were performed. During the preoperative period, all patients underwent NCCT to evaluate the renal anatomy, stone location and screening for the existence of a retrorenal colon. The HU values were calculated for every patient with NeoRAD PACS system version 3.0. Region of interest (ROI) was drawn for every stone as large as possible. Stone burden was calculated by the formula established by European Association of Urology guideline. PT was measured by the NCCT at the planned calyx of puncture.

All PCNL procedures were performed under general anesthesia in prone position. First, 6 fr open ended ureteral catheter was replaced in lithotomy position. Then, the patient was turned to prone position. Collecting system was filled with radiocontrast fluid through the ureteral catheter and the percutaneous entrance was achieved. Track dilatation was performed with Amplatz dilatators (Microvasive/Boston Scientific, Natick, MA). 26 fr nephroscope was inserted into the kidney through 30 fr access and a pneumatic lithotriptor was used to fragment the stones. Before finishing the surgery, the collecting system and the ureteral passage were checked with antegrad pyelography. At the end of the procedure, 14 fr percutaneous mallecot nephrostomy were replaced. Decision for replacing an internal ureteral catheter was based on the suspect for the ureteropelvic junction injury or the presence of mobile residual fragments. Duration of fluoroscopy and operation were documented. Operation time was assumed as the interval between inserting the percutaneous needle and placing the nephrostomy tube. Patients who had no leakage or those with leakage less then 6 h after percutan nefrostomy (PCN) catheter removed were assumed as dry. This period of 6 h is essential, because UL less than this cut-off does not require additional hospital stay.

One month after surgery, stone-free rates were evaluated by ultrasonography (US) or NCCT. The procedure was considered successful if the patient was stone free or had residual fragments < 4 mm.

2.2 Statistical analyses

Statistical analysis was performed using the SPSS software version 18.0. For UL status, the Mann–Whitney *U* test, chi-square tests and logistic regression analyses were used. Univariate and multivariate analyses were used to determine the relationship between the variables and surgery-related motor deficits. The predictive value of HU on UL status was assessed with the receiver operating characteristic (ROC) curve analysis to determine cutoff value. Statistical tests were considered significant at $p < 0.05$. Odds ratios were presented with 95% confidence intervals.

3 Results

Three hundred and ninety-six patients who underwent PCNL for kidney stone, were included in the study. The mean age of the patients was 47.6 ± 13.6 years (range 16–82 years) with 201 (50.8%) males and 195 (49.2%) females. The rate of UL after nephrostomy removal was

40.1%. All data were divided into two groups: whether presence or absence of UL.

The impact of patient related factors on urinary leakage were shown in Table 1. Age, BMI and presence of HT were comparable according to UL status. Women were more likely to have UL than men ($p=0.003$). Furthermore, the presence of DM was significantly correlated with UL ($p=0.000$).

Table 1 Impact of patient related factors on urinary leakage

	Urinary Leakage		*P* value
	Absent (*n* = 237)	Present (n = 159)	
Age	46.8 ± 13.09	48.79 ± 14.27	0.432
Gender (*n*)			0.003
Male	135 (67.1%)	66 (41.6%)	
Female	102 (52.3%)	93 (47.7%)	
Body Mass Index (BMI)	25.5 ± 3.21	25.65 ± 3.99	0.488
HT			0.116
No	153 (62.9%)	90 (37.1%)	
Yes	84 (54.9%)	69 (45.1%)	
DM			0
No	198 (66.6%)	99 (33.3%)	
Yes	39 (39.4%)	60 (60.6%)	

The impact of kidney related factors and stone facts on UL were shown in Table 2. All the stone facts including surface area, burden, localization and HU value had impact on UL. The HU value was 855.98 ± 239.55 in the leakage negative group, and 1215.87 ± 320.01 in the leakage positive group ($p=0.000$, Fig. 1). PT, presence of hydronephrosis (HN) and previous stone treatment history also increased the incidence of UL. When the subgroup analysis was performed according to the severity of HN, we found that there was a statistically significant difference between low-grade HN (grade 0–1) and high-grade HN (grade 2–3) ($p=0.001$). A total of 129 patients (67.5%) with previous stone treatments were included (ESWL, PCNL, open surgery) and another subgroup analysis was performed accordingly. All these procedures were compared in between and we found that patients with previous PCNL or open surgery history were most likely to have UL than patients with no previous stone treatment history and with ESWL history ($p=0.001$).

The impact of surgery related factors on UL status are shown in Table 3. T operation time, fluoroscopy time, stone free status, j stent use, PCN catheter stay time and hospitalization time had significant impact on UL. There was no statistically significant relation between stone HU and predictors of UL.

In addition, all variables were selected for the final multivariate analyses (Table 4). The results showed

Table 2 The impact of kidney related factors and stone facts on urinary leakage

	Urinary leakage		*P* value
	Absent (*n* = 237)	Present (*n* = 159)	
Stone surface area (mm^2)	226.19 (64–1176)	282.74 (106–1374)	0
Stone burden (mm^3)	1558.2 (265–14,951)	2076.21 (623–17,565)	0.003
Stone localization			
Pelvic	142 (70.2%)	60 (29.8%)	0
Isolated caliceal	54 (51.4%)	51 (48.6%)	
Multiple + staghorn	41 (46%)	48 (54%)	
Paranchymal thickness (mm)	13 (9–18)	10 (7–16)	0
Hounsfield unit	855.98 ± 239.55	1215.87 ± 320.01	0
Hydronephrosis grade			
0	126 (77.7%)	36 (22.3%)	0
1	75 (59.5%)	51 (40.5%)	
2	27 (36%)	48 (64%)	
3	9 (27.2%)	24 (72.8%)	
Previous stone treatment history			
No	93 (72%)	36 (28%)	0.001
ESWL	63 (65.6%)	33 (34.4%)	
PCNL	60 (48.7%)	63 (51.3%)	
Open surgery	21 (43.7%)	27 (56.3%)	

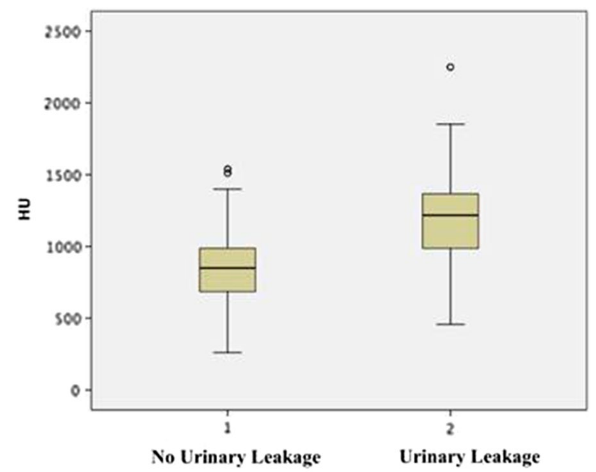


Fig. 1 Box plot of HU values according to urinary leakage status

that, presence of DM (OR 4.64, $p=0.001$), PT (OR 0.77, $p=0.002$), HU value (OR 1.004, $p=0.000$), HN grade (OR 2.61, $p=0.013$), fluoroscopy time (OR 1.485, $p=0.029$), J stent use (OR 0.077, $p=0.000$) and PCN catheter stay time (OR 2.176, $p=0.000$) were independently linked to UL status after nephrostomy removal following PCNL, while the other variables were not significantly associated with UL status.

The predictive value of HU on UL status was analyzed using a ROC curve. Area under curve in ROC curve analyses was 0.827 and it was significant ($p=0.000$). Furthermore, we determined that a HU cutoff value of 933 had 84.9% sensitivity and 67.1% specificity for predicting UL (Fig. 2).

4 Discussion

In the current study, we aimed to evaluate the predictive factors of urinary leakage after PNL catheter removal following PCNL. To the best of our knowledge, this is the first report in the English literature which investigates the relation between the HU values and urinary leakage.

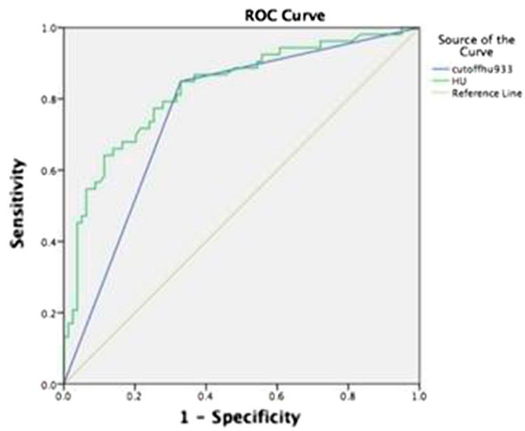
Since the first report of PCNL for kidney stones by Fernastom and Johanssonin in 1976 [2], a steadily increasing number of series have been reported in urological literature. During this period, there has been significant improvement in techniques, instruments and experience. Despite these improvements and high success rates, PCNL still has many complications such as blood loss, urinoma, urosepsis and adjacent organ injury [9]. UL is also a major postoperative complication after PNL catheter removal with a reported incidence up to 70% [3, 4]. In another study, the prevalence of stent requirement after PCNL was reported as 4.3–5% [10]. In our experience, the overall incidence of UL was 40.1% and 11(2.7%) of our patients needed stent replacement.

Table 4 Factors associated with urinary leakage following the PCNL

	OR	95% CI		*P* value
		Min	Max	
DM	4.640	1.944	11.074	0.001
Paranchymal thickness	0.770	0.651	0.910	0.002
Hounsfield unit	1.004	1.003	1.006	0.000
Hydronephrosis grade	2.614	1.222	5.594	0.013
Fluoroscopy time	1.485	1.041	2.118	0.029
J stent use	0.077	0.035	0.169	0.000
PCN catheter stay time	2.176	1.641	2.885	0.000

Table 3 Impact of surgery related factors on urinary leakage

	Urinary leakage		*P* value
	Absent ($n=237$)	Present ($n=159$)	
Operation time (min)	59.37 ± 21.95	74.62 ± 27.47	0
Fluoroscopy time (min)	2.53 ± 1.03	3.65 ± 1.31	0
Treatment outcome			
Failure	30 (31.2%)	66 (68.8%)	0
Stone free	207 (69%)	93 (31%)	
J stent use			
Absent	69 (39.4%)	106 (60.6%)	0
Present	168 (76%)	53 (24%)	
PCN catheter stay time (day)	1.9 ± 0.74	2.58 ± 0.92	0
Hospitalization (day)	3.22 ± 1.23	4.83 ± 1.41	0



Test Result Variable(s)	Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval Lower Bound	Asymptotic 95% Confidence Interval Upper Bound
Cut-off HU 933	.760	.025	.000	.712	.808
HU	.827	.022	.000	.785	.869

Fig. 2 ROC curve of HU predictive value for urinary leakage status

The literature about the BMI effect on PCNL outcomes is unclear. Some reports concluded that BMI had an impact on complication rates of PCNL [11, 12], while some studies noted that BMI did not affect the UL status after PCNL [13, 14]. Dirim et al. [3] noted that BMI did not affect the UL status after PCNL. Our findings are consistent with this report.

To the best of our knowledge, the effect of diabetes mellitus on urinary leakage has not been evaluated before. In the present study, we also found that the presence of DM increased the urinary leakage incidence. As we know, there are many factors that contribute to the altered tissue repair of DM [15]. DM causes microvascular disease which results decreased blood flow and insufficient oxygen delivery. These factors may delay the closure of renal parachimal puncture which may cause urinary leakage. On multivariate analysis, DM was found to be an independent predictive factor for UL after PNL catheter removal.

Dirim et al. [3] and Ansari et al. [4] did not demonstrate correlation between the stone burden and UL. However, as opposed these results, we found that UL was correlated with both stone surface area and stone burden. Additionally, we compared the stone localization and found that multiple calyceal and staghorn stones were also correlated with UL. We thought that all these stone characteristics make surgery more difficult and causes more complications.

Previous studies evaluated the relationship between the hydronephrosis and UL [3, 4, 10]. All these studies concluded that UL increases with the degree of HN. In the present study, we also confirmed the same results. Furthermore, due to our subgroup analyses, UL is statistically significant in high-grade HN (grade 2–3).

The association between renal PT and UL has been investigated in some studies. Uyetürk et al. [16] found 17.2 mm optimum cut-off value of PT for hospitalization $\leq$ 12 h with 90.2% sensitivity and 69.4% specificity. Ansari et al. [4] determined 17 mm cut-off value of PT hospitalization of patients due to prolonged urinary leakage with 95.2 sensitivity and 60.2% specificity. The present study also confirmed that the PT in access line is inversely correlated with UL on multivariate analyses.

The HU values determined in NCCT provide information about stone density and stone formation. There are a lot of publications about HU values and outcomes of the treatment option like SWL and PNL. Quzaid et al. [17] reported that HU threshold of 970 was predictive for successful ESWL. While Gok et al. [18] did not find any correlation between HU values and PNL success rates, Gücük et al. [19] reported higher success rates with lower HU values. Although the correlation between the HU values and success rates has been studied many times until now, the relationship between the HU values and UL status following PCNL procedure has not been discussed in literature so far. In the present study, we hypothesized that the higher HU values would be correlated with UL and multivariate analyses confirmed this hypothesis. We tried to obtain a threshold for HU values. There are no published data on this issue. When we performed the ROC curve analyses, the optimum cut-off value of HU for UL was 933 with 84.9% sensitivity and 67.1% specificity.

Dirim et al. [3] had pointed out that the presence of previous renal stone surgery or SWL treatment had no impact on urinary leakage following PCNL. In subgroup analysis, this study also demonstrates that previous SWL did not affect leakage status, whereas our findings indicate that open surgery or PCNL history had effect on urinary leakage. But on multivariate analyses none of them remained significant.

Differently from the literature, we also evaluated the effect of surgery related factors incluiding operation and fluoroscopy time, treatment outcome, j stent use, PCN catheter stay time and hospitalization time on UL. On univariate analysis we observed that all these factors had effect on urinary leakage. When we performed multivariate analysis, fluoroscopy time, j stent use and PCN catheter stay time were found to be independently and significantly associated with UL.

Our study is not without limitations. First, it has a retrospective design. As it is the first study which investigates the effect of DM presence on UL, we could not reach Hba1c levels for all patients. We only reached the blood glucose levels and arterial tension values during hospitalization time by the clinical progresses.

5 Conclusions

This study demonstrates that the presence of DM, PT through the planned puncture tract, HU value of the stone, presence of HN, fluoroscopy time during the PCNL procedure, j stent use and PCN catheter stay time are significant and independent predictors of urinary leakage status following PCNL. HU values over 933 measured by NCCT may predict urinary leakage after PCN catheter removal.

Abbreviations

UL: Urinary leakage; PCNL: Percutaneous nephrolithotomy; DM: Diabetes mellitus; HN: Hydronephrosis; PCN: Percutenous nephrostomy; HU: Hounsfield unit; BMI: Body mass index; NCCT: Non-contrast computed tomography; HT: Hypertension; US: Ultrasonography; ROC: Receiver operating characteristic; PT: Parenchymal thickness.

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None.

Authors' contributions

TNY: research design, data collection and management, manuscript writing/editing, supervision. EO: protocol development, data collection and management, data analysis, manuscript writing/editing. IS: protocol development, data collection. FUO: protocol development, data collection. NH: protocol development, data collection. BR: protocol development, data collection. HB: protocol development, data collection, supervision. All authors read and approved the final manuscript.

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Availability of data and materials

All articles used in the current review available from the corresponding author on reasonable request.

Declarations

Competing interests

The authors declare that they have no competing interests.

Ethics approval and consent to participate

Ethical committee approval was received from the Dr. Abdurrahman Yurtaslan Training and Research Hospital (approval ID: 19-1762). Written informed consent was obtained from all participants who participated in this study.

Consent for publication

Not applicable.

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