STONE DENSITY HOUNSFIELD UNIT VALUE DETERMINED BY UNENHANCED COMPUTED TOMOGRAPHY IN PREDICTING THE OUTCOME OF PERCUTANEOUS NEPHROLITHOTOMY

Aso O Rashid [a] and Zana Abubakr Sharif [b]

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ABSTRACT

Background

A successful percutaneous nephrolithotomy (PNL) requires appropriate preoperative planning, and non-contrast computerized tomography NCCT has become an important imaging method in diagnosing urolithiasis, providing stone measurements, location, and density (Hounsfield units). Stone density (HU) measurement is routinely performed in clinical practice to define the hardness and composition of kidney stones and predict the stone treatment outcome.

Objective

To evaluate the outcome of percutaneous nephrolithotomy regarding stone-free rate, complications, and operation time using the Hounsfield unit value determined by non-contrast computed tomography.

Patients and Methods

Sixty patients were electively selected for PCNL; the inclusion criteria were all adult patients with renal stones who needed PNL. The exclusion criteria were renal stones in the obstructed pyelonephritic kidney, stone with sepsis, ectopic kidney, and transplanted kidney. The patients were divided into two groups—the low HU group (HU ≤ 1000) and the high HU group (HU> 1000) based on stone density. In addition, the intraoperative and postoperative data, including the operation time, stone-free rate, and post-PCNL complications, were recorded—a comparative study designed between the two differences in HU stone density and the outcome of the procedure.

Results

Our study includes 31 (51.7%) males and 29 (48.3%) females. Twenty-seven patients had an HU value ≤ 1000, and 33 had an HU value >1000. Intraoperative complications occurred in 3 (4.92%) patients with high stone density, including extravasation (n = 2) and bleeding (n = 1). Postoperative complications occurred in 11 (18.03%) patients (nine patients with low and two with high stone density). The postoperative stone residual was found in 4 patients with low stone density. Operation time was longer in high-stone-density groups than in low-stone-density groups (P-value < 0.001).

Conclusion

Preoperative assessment of stone density impacts outcomes in percutaneous nephrolithotomy. High stone densities are associated with longer operating times, higher intraoperative complications, and higher stone-free rates. Conversely, Low-density stone has a shorter operative time, higher postoperative complications, and lower stone-free rates.

Keywords: *Percutaneous nephrolithotomy(PCNL). Hounsfield unit (HU). Stone density. Non-contrast computed tomography (NCCT)*

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[a] College of Medicine. University of Sulaimani, Kurdistan Region, Iraq
[b] Sualimania Teaching Hospital, Ministry of Health, Kurdistan Region, Iraq
Correspondence: zanaabubakr88@gmail.com

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INTRODUCTION

Urolithiasis is a common urological disorder with a high morbidity and recurrence rate, with a prevalence of 10.6% in men and 7.1% in women [1].

Non-contrast computed tomography (NCCT) is the standard imaging method in diagnosing urolithiasis and provides stone measurements and location [2,3]. Because of its high sensitivity of 96% and high specificity of 100%,non-contrast CT was used to identify stone density(Hounsfield units) [4].

Stone density (HU) measurement is routinely performed in clinical practice to define the hardness [5] composition [6, 7] of kidney stones and to predict the outcome of stone treatment [8]. CT images are made up of pixels, each with a grayscale value from 1 (black) to 256 (white). This value corresponds to the number of X-rays that pass through the structure and can be measured and expressed in Hounsfield units (HU). HU has since been used to evaluate and quantify tissues and fluids [9].

Percutaneous nephrolithotomy (PCNL) is a common and successful method with high success rates for a long time [6]. Stone-free rate (SFR) is the key parameter when comparing the efficacy of stone treatments [10]. Percutaneous nephrolithotomy provides high SFRs between 71 and 100% [11]. Residual stones represent a high-risk factor for recurrence and additional treatment within five years after PCNL [12].

While PCNL is a successful and secure procedure, complications can happen, and the modified Clavien grading system classification of surgical complications is the most commonly utilized evaluation method [13].

The most frequent complications of PCNL are fever (21–32.1%), bleeding requiring a blood transfusion (11.2–17.5%), extravasation (7.2%), Septicemia (0.3–4.7%), colon injury (0.2–4.8%), and pleural injury (0–3.1%). Nephrectomy (0.4–1.1%) and patient death (0.05%) are among the serious complications after PCNL [7, 8].

Surgical intervention like PCNL for stone disease aims to attain complete stone clearance [14]. Residual stones represent a high-risk factor for recurrence and additional treatment within five years after PCNL [15].

The conventional technique of post-PCNL imaging for recognizing residual fragments (RF) is a mixture of US and KUB, which overestimates the stone-free rate by 17% to 35%. However, Non-contrast Enhanced computed tomography (NCECT) is regarded as a highly sensitive imaging tool to detect RF post-PCNL [16].

Many research studies have assessed the interconnection between shock wave lithotripsy (SWL) and minimally invasive procedures for treating kidney stones and their HU values, as calculated by non-contrast computed tomography (NCCT) [17–20].

Hence, the present study assesses the impact of the HU value, calculated with the assistance of NCCT, on the consequence of PCNL.

Aim of the study

This study uses the Hounsfield unit value determined by non-contrast computed tomography to evaluate the outcome of percutaneous nephrolithotomy in terms of stone-free rate, complication, and operation time.

PATIENTS AND METHODS

This is an observational study after approval of the ethical and scientific committee of the Iraqi Board of Urology. Between August 2019 and October 2020, 60 patients with renal stones were electively selected for PCNL at Al-Sulaymaniyah Surgical Teaching Hospital urology department.

Patients were informed and given a written document of the procedure. The inclusion criteria were: patients with renal stones were scheduled for PCNL, any mass index.

Renal stones in the obstructed kidney, Urinary tract infection, ectopic kidney, abnormal coagulopathy, and transplanted kidney were excluded. Patients were evaluated by history, physical examination, and investigations, including complete blood count, blood sugar, blood urea, serum creatinine, bleeding profile, viral markers, blood group with crossmatch urinalysis, and urine culture.

All patients had a radiological evaluation with NCCT by an expert radiologist to ease planning for each surgery, detect the value of Hounsfield units, and display the existence of a retro-renal colon.

Patients' data: age, gender, BMI, stone size, location of the stone, hydronephrosis, HU value, fluoroscopy duration, operative time, surgical success, decrease in hematocrit, and complications were recorded.

The patients were split into two groups—the low HU group (HU ≤ 1000) and the high HU group (HU> 1000), established on stone density (HU value). The patients' character, stones character, and renal anatomy were compared in both groups.

A cutoff HU value of 1000 was utilized in this research since the European Association of Urology Guidelines on Urolithiasis designated an HU> 1000 as a factor affecting SWL outcomes [21].

The duration of surgery was recorded from the time of insertion into the skin to the time of re-entry of the nephrostomy tube. A reduction in the hematocrit was calculated established 24 h before and 48 h after PCNL and the measurements of transfused blood (each unit of blood transfused was regarded to increase the hematocrit value by 3 %), accordant with a previously reported method [22].

The procedure of PCNL was performed with the patient under spinal anaesthesia or general anaesthesia. The patients had 3rd generation cephalosporin (ceftriaxone IV 1gm) as a prophylactic antibiotic at the time of induction of anaesthesia.

The same expert endourologist carried a standard procedure for all PCNLs in the prone position.

A Double-JJ stent and nephrostomy were inserted at the end of the operation in all patients. The surgery duration was measured from when the needle was inserted into the skin to the time of re-entry of the nephrostomy tube.

The nephrostomy tube and urethral catheter were removed on the first postoperative day. However, in pelvicalyceal perforation and bleeding, the nephrostomy was kept longer.

A plain abdomen X-ray and ultrasound were performed in all patients 3-4 weeks later to detect residual stones. The Double- JJ was removed after 3-4 weeks.

The method was contemplated successful if no stone or a stone <4 mm was noticed in the collecting system. Because residual stones <4 mm are spontaneously expelled, this size was applied as the definition of PCNL success, and such stones were regarded as clinically insignificant residual fragments [23].

Biochemical analyses were done for removed stones to detect the type and composition of the stone.

The data were taken from the patient's records and the questionnaire. Data collection, entry, and coding were performed using Microsoft Excel Version 2016 (Microsoft et al.). Besides, the "IBM SPSS Statistics version 25" was used to analyze the data, and descriptive and inferential statistics were used. Furthermore, a P-value of ≤0.05 was considered a statistically significant association. Also, Pearson Chi-Square was used to determine the significance of the association between categorical independent and dependent variable pairs. Finally, the Student's T-Test (Paired-Samples T-Test) was used to compare pairs of numerical independent and dependent variables.

RESULTS

Our study includes 31 (51.7%) males and 29 (48.3%) females with a mean age of 43.06 ± 13.48 years (range 22 to 70). The mean BMI was 26.68 ± 2.32 (kg/m). (Table 1) characteristics of the patients and (Table 2) characteristics of the stone.

The PCNL laterality was right in 27 (45%) patients and left in 33 (55%) patients. Fifty-two (86.66%) of the patients had a stone for the first time, and 8 (13.33%) had had previous renal stone surgery, including PCNL in 5 (8.20%) patients and open pyelolithotomy in 3 (4.92%).

Location of the stones was: lower calyces 31(51.66%), pelvis 5 (8.33%), lower calyces and pelvis 9 (15%), partial staghorn 10 (16.66%), complete staghorn 1(1.66%), and upper calyces 4 (6.66%).

Hydronephrosis of the kidney was mild in 17(28.33%) patients, moderate in 9 (15%), and none in 34(56.66%). Urine culture was negative in all 60 (100%) patients.

Twenty-seven patients had an HU value ≤ 1000, and 33 had an HU value >1000.

The mean duration of surgery, according to the Hounsfield units value, was 49.95±8.86 minutes (range 35-70 min) (P-value < 0.001) (Table 3).

Complication intraoperatively happened in 3 (4.92%) patients, including extravasation (n = 2) and bleeding (n = 1), no need for blood transfusion (Table 4), and postoperatively in 11 (18.03%) patients, including fever (Table 5)

The postoperative stone residual was found in four patients, (Table 6).

The biochemical composition of stones according to stone density was calcium oxalate in 35 (57.38%) patients, struvite (magnesium ammonium phosphate) in 11 (18.03%), uric acid in six (9.84%), calcium oxalate, and phosphate in three (4.92%), calcium oxalate and magnesium in 2 (3.28%), cystine stone in two (3.28%) and calcium oxalate and urate in two (3.28%) patients.

Table 1. Characteristics of the patient, stone, and operative data.

Variables	Mean ± SD	Range
Age (year)	41.51 ± 15.84	22 to 70
Weight (kg)	73.18 ± 15.29	60 to 96
Height (cm)	165.67 ± 17.1	142 to 180
Body mass index (kg/m2)	26.31 ± 3.03	23.2 to 30
Preoperative S.Creatinine	0.93 ± 0.17	0.5 to 1.3
Preoperative haemoglobin (gm/dl)	13.76 ± 1.08	11 to 16
Number of ports	1.03 ± 0.18	1 to 2
Size of port (French)	24.69 ± 2.16	16 to 26
Radiation time (sec)	44.34 ± 10.8	25 to 70
Operation time (minute)	49.95 ± 8.86	35 to 70
The normal saline volume used for irrigation (liter)	19.75 ± 4.37	10 to 32
Postoperative Creatinine	0.97 ± 0.17	0.6 to 1.32
Postoperative hemoglobin (gm/dl)	13.18 ± 1.05	10.7 to 15.3
Nephrostomy stay (day)	1.05 ± 0.22	1 to 2
Hospital stay (day)	1.28 ± 0.45	1 to 2

Table 2. Characteristics of the stones.

Location of the stone	Frequency	Percent
Lower calyces	31	51.66%
Pelvis	5	8.33%
Partial staghorn	10	16.66%
Complete staghorn	1	1.66%
Upper calyces	4	6.66%
Lower calyces and pelvis	9	15%
Total	60	100

Table 3. Operation time about Hounsfield units value (HU).

Operation time groups (min)		Hounsfield Unit (HU.)			*P*-value
		<1000	>1000	Total	
35-45	Count	21	1	22	< 0.001
	% of Total	34%	2%	36%	
46-60	Count	5	25	30	
	% of Total	9%	41%	50%	
61-70	Count	1	7	8	
	% of Total	3%	11%	14%	
Total	Count	27	33	60	
	% of Total	46%	54%	100%	

Table 4. Intraoperative complication based on stone density.

Intraoperative complication		Hounsfield Unit (HU) <1000	>1000	Total	*p*-value
Extravasation	Count	1	1	2	0.647
	% of Total	1.6%	1.6%	3.3%	
Bleeding	Count	0	1	1	
	% of Total	0.0%	1.6%	1.6%	
Nil	Count	26	31	57	
	% of Total	44.3%	50.8%	95.1%	
Total	Count	27	33	60	
	% of Total	45.9%	54.1%	100.0%	

Table 5. Postoperative complications based on stone density.

Postoperative fever	Frequency	Percent	Low SD	High SD
Yes	11	18.33	9	2
No	49	81.66	18	31
Total	60	100		

Table 6. Postoperative stone residual based on stone density.

Postoperative stone residual		Hounsfield Unit (HU) <1000	>1000	Total	*p*-value
Yes	Count	3	1	4	0.227
	% of Total	4.9%	1.6%	6.6%	
No	Count	24	32	56	
	% of Total	41.0%	52.5%	93.4%	
Total	Count	27	33	60	
	% of Total	45.9%	54.1%	100.0%	

Table 7. Association between radiation time groups and Hounsfield unit (HU)

Radiation time groups (sec)		Hounsfield Unit (HU) <1000	>1000	Total	*P*-value
25-30	Count	0	4	4	0.005
	% of Total	0.0%	6.6%	6.6%	
31-60	Count	22	29	51	
	% of Total	36.1%	47.5%	83.6%	
61-70	Count	5	0	5	
	% of Total	9.8%	0.0%	9.8%	
Total	Count	27	33	60	
	% of Total	45.9%	54.1%	100.0%	

Table 8. The significance of different Variables concerning Hounsfield Unite

Variable 1	Variable 2	*p*-values
Radiation time	Hounsfield HU Stone density	0.005
Operative time	Hounsfield HU	<0.001
Age	Hounsfield HU	0.216
BMI	Hounsfield HU	0.235
Location of stone	Hounsfield HU	0.803
Hydronephrosis	Hounsfield HU	0.788
Puncture site	Hounsfield HU	0.619
Number of ports	Hounsfield HU	0.185
Size of port	Hounsfield HU	0.354
Nephrostomy	Hounsfield HU	0.459
Hospital stay	Hounsfield HU	0.208
Residual stone	Hounsfield HU	0.227
Chemical composition	Hounsfield HU	0.013
Intraoperative complication	Hounsfield HU	0.647
Stone side	Hounsfield HU	0.471

DISCUSSION

In our study, we prospectively examined the predictive role of Hounsfield units (HU) values determined in unenhanced CT (NCCT) scans in the success rate of PCNL. Fluoroscopic imaging is generally utilized in PCNL to give an entrance to the collecting system and identify the residual stones' location [2]. NCCT has become a dominant imaging routine in planning a standard pre-PCNL intervention, the guidewire's insertion, and the later stages' organization [22]. One more offering of CT imaging is that the HU value, an objective and numerical indicator of calculi opacity, can be calculated. So, HU values can be one of the variables that predict PCNL results. The success rate in PCNL is influenced by the stone burden and the localization of the stones[23].

We searched for a new parameter that could change the success rates: stone density. An HU value of 1000 HU was the cutoff value in our research analysis because it increased the risk of a residual stone (or stones). Residual stone risk has increased when this is accepted as the cutoff value in cases with HU values less than 1000. This increase in residual stones depends on the fact that residual stones cannot be viewed by fluoroscopic imaging. Our study found that SFR in both groups reached 93.4%, and residual stone in both groups was statistically insignificant. However, others suggested that PCNL is an efficient treatment for stones with higher HU values, while low-density stones may be better treated with ESWL [24,25]. Another major finding of our study was the positive connection between HU values and radiation and operation times (Table 8). Patients with high HU values have a longer operation time to break down the hard calculi (Table 3). Still, there is less radiation time due to the greater opacity of stones compared to low HU value patients with longer radiation times and lesser operation times. (Table 7).

In conclusion, preoperative assessment of stone density has an impact on outcomes in percutaneous nephrolithotomy. High stone densities are associated with longer operating times, higher intraoperative complications, and higher stone-free rates. Conversely, Low-density stone has a shorter operative time, higher postoperative complications, and lower stone-free rates.

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