Original Article

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The Impact of Hounsfield Unit-related Variables on Retrograde Intrarenal Surgery Outcomes in Isolated Lower Pole Kidney Stones

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Abstract

Aim: The Hounsfield unit (HU) value can predict the stone-free status of retrograde intrarenal surgery (RIRS) for kidney stones. The purpose of this study was to investigate the effect of HU and HU-related variables on RIRS outcomes in isolated lower pole kidney stones.

Methods: This single-center cross-sectional study was conducted between January 2017 and March 2023. One hundred thirty-three patients who underwent RIRS for lower pole kidney stones were evaluated. These were divided into stone-free (Group 1) and remnant (Group 2) groups, and the effects of the HU-related variables on RIRS outcomes were investigated.

Results: One hundred-five (78.9%) patients in Group 1 and 28 (21.1%) in Group 2 were enrolled in the study. Significant differences were observed between the groups in terms of mean stone area (p=0.003), stone size (p<0.001), use of the ureteral access sheath (p=0.013), and operative time (p<0.001). The mean HU values were 795.09±287.55 in Group 1 and 927.64±302.6 in Group 2 (p=0.034). The mean HU density and HU intensity values were not significantly different between the groups (p=0.432 and p=0.207, respectively). The HU value was not identified as a dependent variable in the regression analysis.

Conclusion: Hounsfield unit value, HU density, and HU intensity are not predictive of stone-free rates after RIRS in isolated lower pole kidney stones.

Keywords: Hounsfield unit, kidney stone, lower pole, retrograde intrarenal surgery

Introduction

The essential objective for treating urinary stone disease is to achieve maximum stone-free status with minimal morbidity. However, the presence of lower pole stones poses a unique challenge due to the anatomical considerations involved in their management and treatment. The development of thin, flexible ureteroscopes (f-URS) with high image quality has facilitated access to every point of the kidney, while retrograde intrarenal surgery (RIRS) for lower pole stones has been facilitated by advances in laser and stone removal instrument technology (1,2). Prospective randomized controlled trials have reported RIRS success rates of 74-95% in isolated lower pole kidney stones (3,4).

The European Association of Urology (EAU) guidelines recommend percutaneous nephrolithotomy (PCNL) as the first-step treatment in isolated lower pole kidney stones >20 mm in size and RIRS or shock wave lithotripsy (SWL) in stones <10 mm. In the case of stones larger than 10 mm but <20 mm in size, RIRS is recommended for first-step treatment in the presence of unfavorable factors. The EAU guideline describes these unfavorable factors as a steep infundibular-pelvic angle, a long calyx, a long skin-to-stone distance, a narrow infundibulum, and shock wave-resistant stones (calcium oxalate monohydrate, brushite, or cystine) (5).

Non-contrast computed tomography (NCCT) is widely employed in the diagnosis of urolithiasis (6). In addition to providing information concerning the stone size, multiplicity, and location, the presence of anatomical anomalies, and skin-to-stone distance, this method is also capable of evaluating the stone density in Hounsfield

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units (HU) values. The HU value determined using NCCT is associated with tissue or stone density. The degree of hardness increases in line with the HU value. These values have been used to predict the type and opacity of stones during diagnosis, and their efficacy has been assessed using therapeutic methods (7). For example, the EAU does not recommend SWL for patients with stone HU values >1,000 (5). Previous studies have assessed the use of HU values in SWL, PCNL, ureterorenoscopic ureterolithotripsy, and medical expulsive treatment in urinary stone disease (7-9). However, no previous studies have examined the predictive role of HU scores in RIRS outcomes in lower pole kidney stones. The primary aim of this study was to identify the association between HU-related variables and RIRS in these stones. The secondary aim was to evaluate our RIRS outcomes in lower pole kidney stones and to present our findings in light of the current literature.

Materials and Methods

The data for patients undergoing RIRS using f-URS due to lower pole kidney stones between January 2017 and March 2023 were then retrospectively evaluated in this cross-sectional study.

Compliance with Ethical Standards

The current study was approved by the Samsun Training and Research Hospital, Clinical Research Ethics Committee (date: 15.03.2023, and approval no: SUKAEK/2023/5/11).

Study Population

The patients were divided into two groups based on their stone-free rate (SFR) status: stone-free (Group 1) and remnant (Group 2).

Inclusion Criteria

- Age over 18, and,
- With a single lower pole stone.

Exclusion Criteria

- Age under 18,
- Who underwent pre-stenting RIRS,
- With isolated non-lower pole kidney stones,
- Undergoing bilateral surgery in the same session,
- Undergoing different kidney stone operations together with RIRS (such as open nephrolithotomy, PCNL, ureterolithotripsy, and antegrade intrarenal surgery) and,
- With a solitary kidney were excluded from the study.

Surgical Technique

All procedures were performed with the patient in the dorsal lithotomy position and under general anesthesia. The bladder was first emptied with a 12 Fr feeding catheter, after which a 0.035-inch safety guidewire was inserted into the ureter under cystoscope-assisted fluoroscopy. A second guidewire was then inserted through the ureteral orifice using a 7 Fr semi-rigid ureterorenoscope (Karl Storz Endoscopy, Tuttlingen, Germany). The ureter was examined endoscopically, and potential distal or middle ureter pathologies were excluded. Balloon dilation was performed in patients with distal ureteral strictures. A second guidewire was then inserted into the ureter. A 7.5 Fr superslim f-URS (Flex-X2, Karl Storz Endoscopy, Tuttlingen, Germany) was then slid over the second guidewire under fluoroscopic control and inserted into the proximal ureter or ureteropelvic region. A 10.7 Fr ureteral access sheath (Cook®, Bloomington, IN, USA) was installed in cases with stones of 15 mm or larger or in which we predicted potential prolongation of the procedure. The stone was identified endoscopically, and stone fragmentation was carried out with a laser lithotriptor in line with the dusting method (Figure 1). Stone fragmentation was performed using a 270 or 365 μm holmium:YAG laser probe in the 1.0-1.5 J and 5-10 Hz energy ranges. In cases in which it is difficult to disintegrate stones in the lower renal pole, the stone can be displaced into a more accessible calyx and fragmented there. Because prolonged operative times are associated with increased complication rates in ureteroscopy, every effort should be made to ensure that surgery lasts no longer than 90 minutes (5). Reasons for the conclusion of RIRS were operative time (>90 min), the

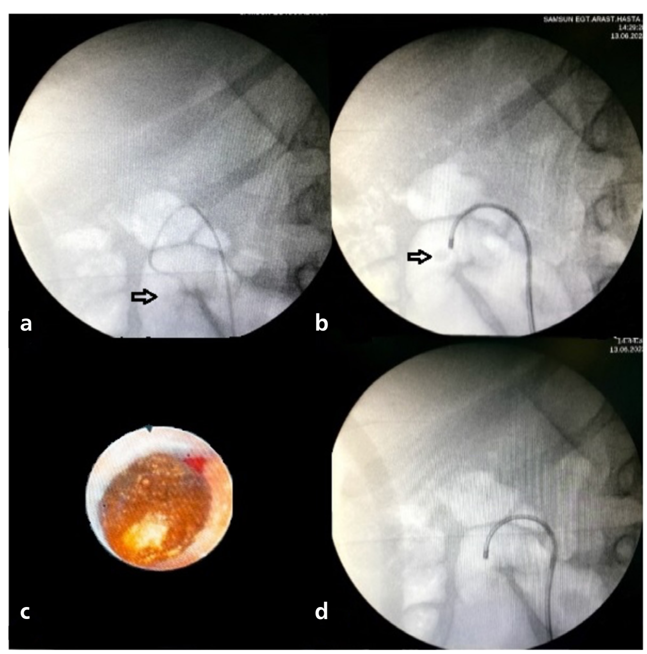

Figure 1. The different stages of retrograde intrarenal surgery. (a) Advancement of the guidewire into the kidney (arrow: Radiological image of the semi-opaque stone); (b) Insertion of a flexible ureteroscope into the kidney with the guidewire; (c) Endoscopic view of the lower pole stone; (d) Stone-free status after laser lithotripsy

removal of the stone, bleeding preventing visualization, or residual fragments <2 mm. A double-J catheter was installed in all patients at the end of the procedure. These were removed 2-4 weeks after surgery, following checking with direct urinary tract imaging (KUB). Patients' third postoperative month stone-free status was evaluated using NCCT. Stone-free status was defined as the absence of stone at NCCT or as residual stone ≤2 mm within three months postoperatively. The urine cultures of all patients were sterile before RIRS.

Postoperative Evaluation

The urethral catheter was removed, and the patient was discharged on postoperative day one. Demographic data, laboratory values, stone-related characteristics, operative characteristics, HU values, and HU-related variables were compared between the groups.

Stone length, stone area, and HU values were calculated automatically from axial and coronal views using the free draw measurement technique from our hospital's electronic records system (Figure 2). Whichever figure was higher for stone length, stone area, and HU value calculated on axial or coronal sections, that value was employed. Hounsfield unit-related variables were calculated using the method first described by Moon et al. (9). HU density was determined by dividing the HU value by the stone length, and HU intensity was determined by dividing the HU value by the stone area.

All patients signed detailed forms agreeing to their clinical details being used in scientific research, a formal requirement under our hospital's regulations.

Statistical Analysis

Normality and variance were evaluated by applying the one-sample Kolmogorov-Smirnov and Shapiro-Wilk tests for each variable. Quantitative data were expressed as mean plus standard deviation and qualitative data as frequency and percentage. The comparisons were completed using an independent sample t-test. Nominal variables were evaluated using the chi-square test. Regression analysis was employed to evaluate the correlation between the data. All analyses were performed using the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA) version 20.0 software. Statistical significance was set at p<0.05.

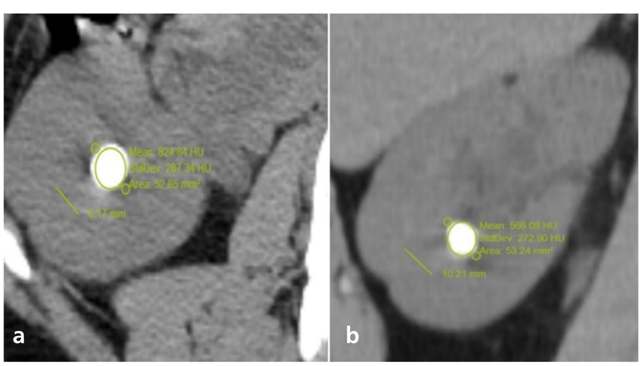

Figure 2. Automatic calculation of renal stone Hounsfield units, stone length, and stone area from coronal (a) and axial (b) views using the free draw measurement technique

Results

One hundred thirty-three patients (48 females and 85 males) with a mean age of 52.84±12.95 years were included in the study. The mean stone area was 87.73±96.94 mm^2 and the mean surgical time was 64.92±16.57 min. The mean American Society of Anesthesiologists score was 1.95±0.6, the ureteral access sheath use rate was 33.1%, the mean length of hospital stay was 2.33±1.08 days, and the SFR was 78.9%.

Mean body mass index values in groups 1 and 2 were 28.11±3.75 and 30.02±3.86 kg/m^2, respectively (p=0.019). The mean stone areas were 75.07±90.57 mm^2 in Group 1 and 135.21±106.7 mm^2 in Group 2 (p=0.003). Significant differences were found between the groups in terms of stone size (p<0.001), ureteral access sheath use (p=0.013), and operative time (p<0.001). The patient group demographic features, stone characteristics, and peri- and postoperative outcomes are listed in Table 1.

Mean HU values were 795.09±287.55 in Group 1 and 927.64±302.6 in Group 2, and the difference was statistically significant (p=0.034). The mean HU density and HU intensity values were not statistically significant (p=0.432 and p=0.207, respectively). Hounsfield unit-related variables are shown in Table 2. Regression analysis was used to evaluate the HU value correlation. Hounsfield unit values were not considered dependent variables (p=0.581).

Grade 2 and higher complications, according to the Clavien-Dindo classification system, developed in 12 patients (9%). These were antibiotics (Grade 2) in eight patients, double J stent placement due to the stent not being in situ (Grade 3a) in two, endoscopic ureter stone surgery (Grade 3b) in one, and sepsis (Grade 4b) in one. There was no difference between the groups in terms of complication rates (p=0.443). No patients developed nephrectomy or died of surgical or anesthesia-related complications.

Discussion

HU values measured using NCCT are associated with the density of the tissue. When the radiodensity of water is defined as 0, fat has a negative HU value, while blood and other tissues exhibit positive HU values. Hounsfield unit values can also be employed to evaluate the NCCT density of urinary tract stones. These values are now a highly useful diagnostic tool not only in terms of predicting the

Table 1. Demographics, stone, procedure characteristics of groups

Variables	Group 1 (n=105)	Group 2 (n=28)	p
Age (years)	52.34±13.65	54.71±9.85	0.391*
Male (n, %)	65 (61.9%)	20 (71.4%)	0.385Ω
Body mass index (kg/m^2)	28.11±3.75	30.02±3.86	0.019*
ASA score	1.93±0.6	2.03±0.57	0.426*
SWL history (n, %)	31 (29.5%)	6 (21.4%)	0.275Ω
Laterality (right)	48 (45.7%)	16 (57.1%)	0.297Ω
Hydronephrosis (n, %)	23 (21.9%)	7 (25)	0.8Ω
Radio opacity (n, %)	78 (74.3%)	22 (78.6%)	0.807Ω
Stone size (mm)	9.48±3.19	12.71±4.38	<0.001*
Stone area (mm^2)	75.07±90.57	135.21±106.7	0.003*
Operation time (min)	61.85±16.02	76.42±13.4	<0.001*
Ureteral access sheath (n, %)	29 (27.6%)	15 (53.6%)	0.013Ω
Hospital stay (day)	2.32±1.1	2.39±1.03	0.766*

*Independent Samples t-test, ΩChi-square test.
ASA: American Society of Anesthesiologists, SWL: Shock wave lithotripsy

Table 2. The groups' HU, HU density, and HU intensity values

Variables	Group 1 (n=105)	Group 2 (n=28)	p*
HU	795.09±287.55	927.64±302.61	0.034
HU density (HU/mm)	85.6±35.34	80.07±21.86	0.432
HU intensity (HU/mm^2)	16.73±10.48	13.9±10.58	0.207

*Independent Samples t-test.
HU: Hounsfield unit

type of stone but also for determining the optimal form of treatment (7).

HU is a frequently employed method for the treatment of urinary system stone disease. According to the EAU guideline, an HU value exceeding 1000 in lower pole stones 10-20 mm in size is an unfavorable factor in terms of success (5). In their 20-center, 4208-patient study comparing RIRS and laser lithotripsy, Keat et al. (8) divided their patients into two groups: one with HU values above 1000 and another with values below 1000. These authors reported that the stones with HU values lower than 1000 were soft stones. In a review study examining the effect of HU on SWL, Garg et al. (7) found that HU<750 was associated with SWL success, while HU values over 1000 were strongly associated with a likelihood of failure. However, Moon et al. (9) reported no relationship between HU and PCNL success.

Lower pole kidney stones represent approximately 35% of all renal stones and are completely asymptomatic in many cases. However, their treatment is problematic because fragments are difficult to eliminate and have limited anatomical access to the inferior renal calyx (10). The American Urological Association and EAU have both issued guidelines and recommendations concerning the management of such stones (5,11). However, since all individuals' renal anatomy differs, the two guidelines differ slightly from one another and both involve deficiencies for treating lower pole kidney stones (12). For example, while the EAU explicitly describes those patients for whom SWL should not be performed, it says nothing specific about which individuals are suitable for RIRS (5).

Previous studies have described anatomical factors such as infundibulopelvic angle, pelvicalyceal height, and infundibular length and stone-related factors such as size and opacity as independent factors affecting the success of RIRS in lower pole kidney stones (13-15). The present study investigated the effect of HU values, HU density, and HU intensity in such stones on the effect of RIRS. Hounsfield unit values were significantly higher in Group 2, whereas no difference was observed between the two groups in terms of HU density or intensity. All three parameters were found not to constitute an independent factor for SFR in RIRS for lower pole kidney stones. Moon et al. (9) investigated the effects of the HU value and its variants on PCNL and concluded that while HU score and HU density were not factors in SFR in PCNL, HU intensity was an independent risk factor for SFR in that procedure. Li et al. (16) concluded that the HU value is not an independent risk factor for SFR in RIRS and PCNL but that it is closely associated with surgical time in RIRS. In their randomized, prospective, controlled study, Gucuk et al. (17) reported that the HU value had no effect on SFR in RIRS performed due to lower pole kidney stones. Although the present study involved isolated lower pole kidney stones, from that perspective, our results are similar to those of other kidney stone studies.

Prospective randomized controlled trials have also reported SFR between 74% and 95% in isolated lower pole kidney stones (3,4,17). Similar to this research, retrospectively designed studies have reported SFR values of 62.5% to 93.8% (18-21). The SFR value in the present research was 78.9%. In terms of SFR, our research is thus consistent with previous studies in the literature.

The general complication rate of RIRS for treating lower pole kidney stones was as high as 40% in previous studies, although the majority of these complications were minor and required no intervention. Severe complications such as ureteral avulsion, arteriovenous fistulae, and severe kidney injuries have been reported in the following f-URS, but are unusual (10). Mortality rates are low in ureteroscopy for stone disease, with 72 cases having been reported in the literature (22). Rates of Grade 2 or higher complications associated with RIRS in lower renal pole kidney stones of 6.67%, 7%, and 9.9% were reported in three different prospective studies (16,17,23). The grade 2 and higher complication rate in this study was 9%. The most feared complication, sepsis, was observed in one patient (0.07%) but was successfully treated. Our study is also consistent with previous research in terms of complication rates.

Study Limitations

There are some limitations to this study. One is specific to its retrospective and single-center character. The patient number was also low. In addition, because we investigated the degree of stone hardness, anatomical factors involving the pelvicalyceal structure, such as infundibular height and length, infundibular pelvic angle, and infundibular width, were not included in this study. Finally, we excluded the analysis of stone composition. Despite these limitations, there are also some strengths to this study. These include the low number of previous studies on the subject, the fact that it focused specifically on the lower pole alone, and the fact that it is one of the first studies to compare HU and HU-related variables in RIRS.

Conclusion

Stone density measured in terms of HU values was significantly higher in patients with residual stone fragments in this study. Our findings suggest that HU and HU-associated variables are capable of predicting SFR of RIRS in the renal lower pole. We anticipate that subsequent multicenter prospective studies will confirm that HU and HU-associated variables are capable of application as a useful tool in determining the SFR of ureteroscopic surgical procedures.

Ethics

Ethics Committee Approval: The current study was approved by the Samsun Training and Research Hospital, Clinical Research Ethics Committee (date: 15.03.2023, and approval no: SUKAEK/2023/5/11).

Informed Consent: Retrospective study.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Concept: E.A., Design: E.A., M.U., Data Collection or Processing: E.A., M.U., Analysis or Interpretation: E.A., M.U., Literature Search: E.A., M.U., Writing: E.A., M.U.

Conflict of Interest: No conflict of interest was declared by the authors.

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