Advanced Medical Journal, Vol.9, No.4, P.46-54,2024 https://doi.org/10.56056/amj.2024.297

Impact of stone density on the total laser time and other surgical outcomes in flexible ureteroscopy

Aso Omer Rashid* Sarwar Noori Mahmood Mohammed Ismael Nader*****

Abstract

Background and objectives: Several preoperative factors are assessed for the evaluation of operative time and fragmentation efficacy during retrograde intrarenal surgery. Due to limited energy capabilities, stone density is an important factor contributing to procedural time. This study aimed to evaluate the effect of stone density on the total laser time in lithotripsy.

Methods: We conducted a cross-sectional prospective analysis where fifty-two patients who underwent flexible ureteroscopy using the Cyber Ho 60 holmium laser system (Quanta System) were prospectively analyzed from October 2017 to November 2020 in a cross-sectional study. These patients were divided into groups according to their stone attenuation values (Hounsfield units) and were followed up for 3 months to determine the success of stone clearance.

Results: The mean stone size and density were 14.44 mm and 1043 Hounsfield units, respectively. Furthermore, the mean total laser time was 26.58 minutes, whereas the mean operative time was 41.44 minutes. The total laser time did not significantly differ between stones with attenuation >1000 and those with attenuation <1000 ($p = 0.486$). Stones measuring >13 mm in size required considerably longer lasering time than their smaller counterparts ($p = 0.008$).

Conclusion: In the era of rapid laser technology and instrumental developments, our findings suggest that stone density has no value on the outcomes of flexible ureterorenoscopy, including the total lasering time, stone-free rate, and overall complications. In contrast, stone size significantly influences the total laser time and stone-free rate.

Keywords: Flexible ureterorenoscopy, Holmium: yttrium-aluminum-garnet laser, Hounsfield unit, Total laser time.

---

* MBChB FICMS, Professor, Sulaymaniyah University. E-mail: aso.rasheed.@univsul.edu.iq. Corresponding author.
**MBChB FICMS, Professor, Sulaymaniyah University. E-mail: sarwar.mahmood@univsul.edu.iq
***MBChB, Board trainee, Sulaymaniyah teaching hospital. E-mail: mohammed.ismaiel@gmail.com

Introduction

Renal stones are common, affecting 7% of women and 13% of men. Recurrence rates can be as high as 50% over five years if left untreated.[1] Renal colic is often seen in emergency hospitals, and 20% of patients need urologic treatment.[2] Over the past three decades, surgical management of renal stones has made significant advancements. Highly effective minimally invasive techniques like extracorporeal shock wave lithotripsy (ESWL), semi-rigid flexible ureteroscopy (fURS), and percutaneous nephrolithotomy (PCNL) have been developed.[3] Extra corporeal shockwave lithotripsy is still a good treatment for kidney and ureteral stones, despite newer options. It costs less, but requires more procedures.[4] Percutaneous nephrolithotomy is the preferred treatment method for large renal stones, and its effectiveness surpasses that of other minimally invasive procedures. However, PCNL is associated with a higher risk of complications, such as bleeding.[5] Retrograde ureteroscopy, retrograde intrarenal surgery (RIRS), and percutaneous nephrolithotomy (PCNL) are common interventions for treating renal and ureteral stones but carry risks of serious adverse events.[6] These techniques have revolutionized renal stone management, offering patients safer and more effective treatment options that depend on several factors including stone characteristics, preoperative stone size, location, and density measured on computed tomography.[7,8, 9] Concerning the achievement of a stone-free status, fURS with a holmium: yttrium-aluminum-garnet (Ho: YAG) laser is a safe and effective procedure, particularly for stones measuring up to 20 mm in size and is recommended by both the European Association of Urology and the American Urological Association.[10–12] The popularity of Ho: YAG laser systems for laser lithotripsy can be partially attributed to their wide availability and advanced features. The Ho: YAG laser operates at a wavelength of 2100 nm, with a pulse duration of 250–350 µs, pulse energy of 0.2–4.0 J/pulse, frequency of 5–45 Hz, and average power of 30–80 watts. The use of high-power lasers allows for faster stone lithotripsy, shorter operative time, and fewer patients requiring a second procedure to achieve a stone-free status compared to low-power lasers. However, one of the drawbacks is the steep cost involved.[13,14] Difficulties arise when high-density stones are fragmented, leading to incomplete removal, long procedures, and elevated morbidity rates.[15] The predictive power of stone volume and average Hounsfield units (HU) cannot be underestimated when it comes to determining the total laser time (TLT) and energy needed during ureteroscopy. These factors hold significant ways and should be taken into account for optimal outcomes.[16] It has been observed that the density of the stone may affect both the efficiency of fragmentation and the length of laser therapy.[17–19] Our clinical study aimed to evaluate the effect of stone density on the TLT and fURS outcomes across various parameters including total operative time and effect on patient morbidity.

Patients and methods

Our study was a cross-sectional prospective analysis which followed ethical guidelines and patients provided informed consent. This prospective observational study was conducted at the urological department from October 2017 to November 2020 and included a total of 52 patients who underwent RIRS and laser fragmentation for a single unilateral stone (size: <20 mm) in the upper ureter/renal pelvis or upper calyx. The inclusion criteria were as follows: age ≥18 years; the presence of a single stone in the upper ureter/renal pelvis or upper calyx that required minimal fURS deflection to reach (to eliminate the factor of stone location, which might impact our results); stone not exceeding 20 mm in size; any weight; and patients with ureteral tightness who previously received a double-J stent prior to the study. The exclusion criteria were as follows: congenital anomalies, such as ectopic kidney, horseshoe kidney, and duplex system; ureteropelvic junction obstruction; untreated urinary tract infection; pregnancy; multiple renal stones; presence of stones in the lower and middle calyces; stone exceeding 20 mm in size; and refusal to participate in the study. All patients underwent a thorough physical examination and medical history review. Data on age, sex, and body mass index were obtained. Necessary investigations, including abdominal ultrasound and plain kidney-ureter-bladder (KUB) radiography, were conducted preoperatively. An expert uro-radiologist performed non-contrast computed tomography (NCCT) of the abdomen to measure the stone dimensions and density (HU) and to detect any hydronephrosis. All patients underwent urinalysis, urine culture evaluation, and hematological and renal function tests. The TLT, stone-free rate (SFR), and complications were all recorded.

The guidelines on urolithiasis issued by the European Association of Urology consider an HU of >1000 as a factor that could influence the outcomes of shock wave lithotripsy. Hence, in the present study, an HU cutoff value of 1000 was adopted to measure the stone density in relation to the TLT. The treated patients were divided into two groups according to their HU readings, the low HU (HU ≤1000) and high HU (HU >1000) groups. Both groups were nearly identical with respect to patient characteristics, stone type, and renal structure. The patients were treated with a designated antibiotic for 1 week preoperatively. At 30 min prior to the operation, a third-generation cephalosporin was administered as an antibiotic, unless urine culture yielded positive results. After anesthesia induction, the patients were placed in the lithotomy position. Semi-rigid ureterorenoscopy was performed using a 7.5- or 9-Fr endoscope to evaluate and dilate the ureter. Subsequently, a 0.032- or 0.035-inch Zebra™ nitinol guidewire was introduced into the pelvis. A 9.5/11.5-Fr, 10/12-Fr, or 11/13-Fr ureteral access sheath was carefully inserted over the guidewire and checked by fluoroscopy.A 7.5-Fr flexible ureterorenoscope was introduced, and the stone was accessed. Lithotripsy was performed with the Ho:YAG laser using dusting and fragmentation techniques. The initial laser settings were set at a power of 0.8–1.2 J applied at a frequency of 10–15 Hz and were modified upon the operator's request. Careful endoscopic inspection and postoperative C-arm X-ray imaging were performed to assess stone clearance, and retrograde pyelography was performed to identify any extravasation. A double-J stent was inserted intraoperatively, and a urethral Foley catheter was placed at the end of the operation. Operative time was defined as the time from the start of endoscopy to double-J stent insertion. TLT was defined as the time from the beginning of laser lithotripsy to complete stone fragmentation. Patients with no visible fragments or clinically insignificant residual fragments (fragments measuring ≤4 mm that were asymptomatic, non-infectious, and associated with sterile urine) were deemed to be "stone-free". The urethral Foley catheter was removed on postoperative day 1. Postoperative complications were recorded using the Clavien–Dindo classification system for surgical complications. Patients were followed up 2–3 weeks postoperatively. The patients were examined using plain KUB radiography with ultrasound evaluation; patients with no fragments or clinically insignificant residual fragments were considered successful and scheduled for double-J stent removal. Ethical approval was obtained and participants gave informed consent. Each participant completed a consent form that included comprehensive information about the research's goals, how medical examination results will be utilised, data confidentiality, and the right to withdraw. Before beginning data collection, the Kurdistan Higher Council of Medical Specialties (KHCMS) authorized the initiation of the study. The collected data were entered into an Excel sheet, which was subsequently imported into and analyzed using SPSS software v. 27 for Windows (IBM Corp., Armonk, NY, USA). Categorical variables are expressed as frequencies and proportions, and differences between the groups were examined using the chi-squared test. Numerical variables are expressed as means and standard deviations. The mean difference was analyzed using Student's independent t-test. Statistical significance was set at $p < 0.05$.

Results

A total of 52 patients (30 men and 22 women; mean age: 43.33 ± 13.78 years) underwent fURS. The mean stone size was 14.44 ± 3.56 mm, and the mean stone density was 1043 ± 335.2 HU. Overall, 31 and 21 patients had left-sided and right-sided stones, respectively. The mean TLT was 26.58 ± 13.44 min, whereas the mean operative time was 41.44 ± 16.67 min; the mean length of hospital stay was 1.08 ± 0.334 day, as presented in Table (1).

Table (1): Characteristics of the study population

Variables	Frequency *N* = 52	Percentage (%)
Sex		
Male	30	57.7
Female	22	42.3
Age, years (mean (SD))	43.33 (13.78)	
ASA physical status		
1	36	69.2
2	10	19.2
3	5	9.6
4	1	1.9
Lateralization (renal unit)		
Right	21	40.4
Left	31	59.6
Stone size (mm)		
≤13	25	48.1
>13	27	51.9
Stone density (mean (SD))	1043 (335.2)	
Stone size, mm (mean (SD))	14.44 (3.56)	
Laser time, min (mean (SD))	26.58 (13.44)	
Length of hospital stay, day (mean (SD))	1.08 (0.334)	
Operative time, min (mean (SD))	41.44 (16.67)	

SD standard deviation, ASA American Society of Anesthesiologists

The patients were divided into two groups according to stone density; the low HU group, comprising 24 (46.15%) patients with density ≤1000 HU, and the high HU group, comprising 28 (53.84%) patients with density >1000 HU, as shown in Table (2). For statistical analysis, the patients were also classified into the following three laser groups: the first group comprised 24 (46.2%) patients with TLT of 10–24 min; the second group comprised 23 (44.2%) patients with TLT of 25–40 min; and the third group comprised five (9.6%) patients with TLT of >40 min. Our analysis revealed that the overall correlation between stone density and the TLT was not significant ($p = 0.486$).

Table (2): Relationship between stone density and the TLT

TLT (min)	Frequency (%)	Soft stones ≤1000 HU, *n* (%)	Hard stones >1000 HU, *n* (%)	p-value
10–24	24 (46.2)	9	15	0.486[*]
25–40	23 (44.2)	12	11	
>40	5 (9.6)	3	2	
Total	52 (100)	24 (46.15%)	28 (53.84%)	

[*] Chi-squared test

TLT total laser time, HU Hounsfield units

Table (3) shows the relationship between stone size and the TLT. Among 24 patients in the first TLT group, 17 had stone size ≤13 mm, whereas seven had stone size >13 mm. Among 23 patients in the second TLT group, six had stone size ≤13 mm, whereas 17 had stone size >13 mm. Among five patients in the third TLT group, two had stone size ≤13 mm, whereas three had stone size >13 mm. Stone size showed a significant correlation with the TLT (*p* = 0.008). In our analysis, we also attempted to determine the impact of stone density on other surgical outcomes.

Table (3): Relationship between stone size and the TLT

TLT (min)	Frequency (%)	Stone size ≤13 mm, *n* (%)	Stone size >13 mm, *n* (%)	p-value
10–24	24 (46.2)	17 (68)	7 (25.9)	0.008*
25–40	23 (44.2)	6 (24)	17 (63)	
>40	5 (9.6)	2 (8)	3 (11.1)	
Total	52 (100)	25 (100)	27 (100)	

* Chi-squared test
TLT total laser time

Table (4) shows the relationship between stone density and the SFR. The patients were categorized into the following five groups according to the SFR: (i) the immediate group, which presented with stones that completely turned into dust at the time of the procedure; (ii) the 2-week group, which showed no evidence of residual fragment on imaging after 2 weeks; (iii) the 4-week group, which had no fragments at 4 weeks; (iv) the 6-week group; and (v) the residual group, which had fragments that were still present after 3 months. Among 15 (28.8%) patients in the immediate group, six had soft stones, whereas the remaining nine had hard stones. Among 15 (28.8%) patients in the 2-week group, seven had soft stones, whereas eight had hard stones. The 4-week group included only one (1.9%) patient with a hard stone. The 6-week group comprised 11 (21.2%) patients, of whom five and six had soft and hard stones, respectively. Among 10 (19.2%) patients in the residual group, six had soft stones, whereas four had hard stones. Our analysis indicated that stone density had a non-significant effect on the SFR (*p* = 0.761). As another surgical outcome of fURS, postoperative complications were analyzed and graded using the Clavien–Dindo classification system. Table (5) shows the relationship between stone density and postoperative complications.

Table (4): Relationship between stone density and the SFR

SFR	Frequency (%)	Soft stones <1000 HU, *n* (%)	Soft stones <1000 HU, *n* (%)	p-value
Immediate	15 (28.8)	6 (25)	9 (32.1)	0.761*
At 2 weeks	15 (28.8)	7 (29.2)	8 (28.6)	
At 4 weeks	1 (1.9)	0 (0)	1 (3.6)	
At 6 weeks	11 (21.2)	5 (20.8)	6 (21.4)	
Residual (3 months)	10 (19.2)	6 (25)	4 (14.3)	
Total	52 (100)	24 (100)	28 (100)	

* Chi-squared test
SFR stone-free rate, HU Hounsfield units

Table (5): Relationship between stone density and postoperative complications graded using the Clavien–Dindo classification system

Postoperative complications	Frequency (%)	Soft stones <1000 HU, *n* (%)	Hard stones >1000 HU, *n* (%)	p-value
CDS grade 1	9 (17.3)	4 (16.7)	5 (17.9)	0.989*
CDS grade 2	2 (3.8)	1 (4.2)	1 (3.6)	
Nil	41 (78.8)	19 (79.2)	22 (78.6)	
Total	52 (100)	24 (100)	28 (100)	

* Chi-squared test
CDS Clavien–Dindo score, HU Hounsfield units

Grade 1 complications were observed in nine (17.3%) patients (four with soft stones and five with hard stones). Grade 2 complications were observed in two (3.8%) patients (one with soft stone and one with hard stone). No complications were observed in 41 (78.8%) patients. Our analysis revealed that stone density also had a non-significant effect on postoperative complications (p = 0.989). Table (6) shows the relationship between stone density and other variables. The operative time was 42.50 min (16.22%) for patients with stone density <1000 HU and 40.54 min (17.29%) for those with stone density >1000 HU; however, there was no statistically significant difference (p = 0.676). Furthermore, the degree of hydronephrosis (p = 0.356), length of hospital stays (p = 0.9), postoperative urea and creatinine levels (p = 0.921 and p = 0.32, respectively), and preoperative stent placement (p = 0.335) were statistically non-significant in relation to stone density. The postoperative hemoglobin levels and the presence of ureteral access sheath were the only two variables found to be positively correlated with stone density (p = 0.01 and p = 0.046, respectively).

Table (6): Relationship between stone density and different variables

Variables	Soft stones <1000 HU, *n* (%)	Hard stones >1000 HU, *n* (%)	p-value
Operative time, min	42.50 (16.22)	40.54 (17.29)	0.676[*]
Degree of hydronephrosis			0.356[**]
0	0 (0)	3 (10.7)	
1	10 (41.7)	8 (28.6)	
2	13 (54.2)	16 (57.1)	
3	1 (4.2)	1 (3.6)	
Length of hospital stay, day	1.08 (0.28)	1.7 (0.38)	0.90[*]
Postoperative urea levels, mg/dL	32.63 (12.82)	32.93 (9.09)	0.921[*]
Postoperative creatinine levels, mg/dL	1.014 (0.495)	0.904 (0.281)	0.320[*]
Postoperative hemoglobin levels, mg/dL	13.29 (1.18)	14.24 (1.35)	0.01[*]
Preoperative stent placement			0.335[**]
No	17 (70.8)	23 (82.1)	
Yes	7 (29.2)	5 (17.9)	
Presence of ureteral access sheath			0.046[**]
No	16 (66.7)	25 (89.3)	
Yes	8 (33.3)	3 (10.7)	
Postoperative complications			0.594[**]
No	21 (87.5)	23 (82.1)	
Yes	3 (12.5)	5 (17.9)	

[*] Student's independent t-test
[**] Chi-squared test
HU Hounsfield units

Discussion

The present study evaluated the preoperative stone density (HU) measured by NCCT. It correlates it with the TLT used Ho:YAG laser during RIRS rather than real operative time, which might vary depending on few factors, along with the clinical and radiological outcome of RIRS abolishing the element of stone location as much as possible to find out whether the change in TLT to stone attenuation will translate into less morbidity for the patient and better cost saving due to the high price of fiber and software in the era of new-generation laser systems. Our analysis revealed that stone attenuation in both groups had a minimal impact on the TLT ($p = 0.486$), which contradicts the findings of Roshane et al., who reported a strong correlation between HU and the TLT ($r = 0.58$, $p = 0.001$).[11] Ashmawy et al. identified HU and stone diameter are significant predictors of the total laser energy and TLT when using the Ho:YAG laser for stone fragmentation.[20] Compared to the current study, Ashmawy et al. used different laser power supply systems (100-W Ho:YAG; LISA Laser Products GmbH, Katlenburg-Lindau, Germany) and various fibers. Additionally, the size of the stones was <30 mm in the study by Ashmawy et al., compared to <20 mm in our study. Kronenberg et al. concluded that several technical factors, such as lithotripter settings, fibers, and newly developed long-pulse modes, could influence the performance of holmium laser.[21] In our study, the overall SFR was 80.7% in a single session, and stone density was not significantly correlated with the SFR ($p = 0.76$). These results are consistent with the findings of Basatac et al., who analyzed 473 consecutive RIRS patients. In their study, 84.1% of patients in the low-density (LD) group and 87% of patients in the high-density (HD) group achieved stone-free status; however, the difference between these two groups was not statistically significant ($p = 0.27$). Furthermore, our study demonstrated that stone size significantly affected the TLT and SFR ($p = 0.008$), which is in agreement with the findings of Ito et al. and Hussain et al., who evaluated the average stone density in RIRS patients and reported that stone density (HU) by itself did not affect the SFR, whereas stone burden and number were significant factors.[16, 22] Molina et al. revealed the same contribution of stone dimension to the TLT, as well as its significant correlation with stone hardness, location, fiber size, and power.[18] In the present study, the overall complication rate was 21.2% (11 patients), with five and six patients in the LD and HD groups, respectively; $p = 0.98$), suggesting the absence of an association between stone density and postoperative complications. This result aligns with the overall complication rate reported by a previous study (15.2% and 21.1% for the LD and HD groups, respectively; $p = 0.16$).[23] We also observed that ureteral access sheath positively correlated with stone density ($p = 0.046$). This observation can be mainly attributed to minimizing external forces on the flexible scope (and, therefore, the laser fiber) by the sheath, leading to better energy conduction and more efficient fragmentation. This study had some limitations. In particular, ultrasound evaluation and KUB radiography were performed instead of CT imaging to assess postoperative stone clearance, which might have affected the final SFR and residual fragments.

Conclusion

In the era of rapid laser technology and instrumental developments, our findings suggest that stone density has no value on the outcomes of fURS, including the TLT, SFR, and overall compilations. In contrast, stone size significantly affects the TLT and SFR.

Conflict of interest:

The authors have no competing interests to declare relevant to this article's content.

References

1. Chew BH, Brotherhood HL, Sur RL, Wang AQ, Knudsen BE, Yong C, et al. Natural history, complications and re-intervention rates of asymptomatic residual stone fragments after ureteroscopy: a report from the EDGE research consortium.J Urol. 2016;195(4 Pt 1):982-6.
2. Corbo J, Wang J. Kidney and ureteral stones. Emerg Med Clin North Am. 2019; 37:637–48.
3. Rodríguez-Monsalve Herrero M, Doizi S, Keller EX, De Coninck V, Traxer O. Retrograde intrarenal surgery: an expanding role in treatment of urolithiasis. Asian J Urol. 2018; 5: 264–73.
4. Talso M, Tefik T, Mantica G, Rodriguez Socarras M, Kartalas Goumas I, Somani BK, et al. Extracorporeal shockwave lithotripsy: current knowledge and future perspectives. Minerva Urol Nefrol. 2019; 71: 365–72.
5. Knoll T, Daels F, Desai J, Hoznek A, Knudsen B, Montanari E, et al. Percutaneous nephrolithotomy: technique. World J Urol. 2017; 35: 1361–8.
6. Grosso AA, Sessa F, Campi R, Viola L, Polverino P, Crisci A, et al. Intraoperative and postoperative surgical complications after ureteroscopy, retrograde intrarenal surgery, and percutaneous nephrolithotomy: a systematic review. Minerva Urol Nephrol. 2021; 73: 309–32.
7. Kaygısız O, Aydın YM, Çiçek MÇ, Polat R, Coşkun B, Ocakoğlu G, et al. The predictive factors that total laser energy consumed during retrograde intrarenal surgery (RIRS): stone area and density. Lasers Med Sci. 2023; 38: 128.
8. Anastasiadis A, Onal B, Modi P, Turna B, Duvdevani M, Timoney A, et al. Impact of stone density on outcomes in percutaneous nephrolithotomy (PCNL): an analysis of the Clinical Research Office of the Endourological Society (CROES) PCNL Global Study Database. Scand J Urol. 2013; 47: 509–14.
9. Assimos D, Krambeck A, Miller NL, Monga M, Murad MH, Nelson CP, et al. Surgical management of stones: American urological association/endourological society guideline, PART I. J Urol. 2016; 196: 1153−60.
10. Aboumarzouk OM, Monga M, Kata SG, Traxer O, Somani BK. Flexible ureteroscopy and laser lithotripsy for stones >2 cm: a systematic review and meta-analysis. J Endourol. 2012; 26: 1257–63.
11. Mi Y, Ren K, Pan H, Zhu L, Wu S, You X, et al. Flexible ureterorenoscopy (F-URS) with holmium laser versus extracorporeal shock wave lithotripsy (ESWL) for treatment of renal stone <2 cm: a meta-analysis. Urolithiasis. 2016; 44: 353–65.
12. Benson DA, Maxwell RM, Poeter E, Ibrahim H, Dean A, Revielle J, et al. EAU guidelines on urolithiasis. Eur Assoc Urol. 2019; 49: 1–88.
13. Pietropaolo A, Hughes T, Mani M, Somani B. Outcomes of ureteroscopy and laser stone fragmentation (URSL) for kidney stone disease (KSD): comparative cohort study using MOSES technology 60 W laser system versus regular holmium 20 W laser. J Clin Med. 2021; 10: 27–42.
14. Sandhu AS, Srivastava A, Madhusoodanan P, Sinha T, Gupta SK, Kumar A, et al. Holmium: YAG laser for intracorporeal lithotripsy. Med J Armed Forces India. 2007; 63:48–51.
15. Mekayten M, Lorber A, Katafigiotis I, Sfoungaristos S, Leotsakos I, Heifetz EM**,** et al, Will stone density stop being a key factor in endourology? The impact of

stone density on laser time using Lumenis laser p120w and standard 20 W laser: a comparative study. J Endourol. 2019; 33: 585–589.

16. Ito H, Kawahara T, Terao H, Ogawa T, Yao M, Kubota Y, et al. Predictive value of attenuation coefficients measured as Hounsfield units on noncontrast computed tomography during flexible ureteroscopy with holmium laser lithotripsy: a single-center experience. J Endourol. 2012; 26: 1125–30.
17. Rosa M, Usai P, Miano R, Kim FJ, Finazzi Agrò E, Bove P, et al. Recent finding and new technologies in nephrolitiasis: a review of the recent literature. BMC Urol. 2013; 13(1): 1–11.
18. Molina WR, Marchini GS, Pompeo A, Sehrt D, Kim FJ, Monga M. Determinants of holmium:yttrium-aluminum-garnet laser time and energy during ureteroscopic laser lithotripsy. Urology. 2014; 83: 738–44.
19. Kim DS, Moon SK, Lee SH. Histogram of kidney stones on non-contrast computed tomography to predict successful stone dusting during retrograde intrarenal surgery. World J Urol. 2021; 39: 3563–9.
20. Ashmawy A, Khedr M, Saad IR, Zamel S, Kassem A. Laser lithotripsy using dusting technique (low energy, high frequency) for symptomatic upper urinary tract stones. Afr J Urol. 2021; 27(1): 1–6.
21. Kronenberg P, Traxer O. Update on lasers in urology 2014: current assessment on holmium:yttrium-aluminum-garnet (Ho:YAG) laser lithotripter settings and laser fibers. World J Urol. 2015; 33: 463–9.
22. Hussain M, Acher P, Penev B, Cynk M. Redefining the limits of flexible ureterorenoscopy. J Endourol. 2011; 25: 45–9.
23. Basatac C, Özman O, Akgül HM, Ozyaman O, Cinar O, Can G, et al. The impact of stone density on operative complications of retrograde intrarenal surgery: a multicenter study with propensity scores matching analysis. J Laparoendosc Adv Surg Tech A. 2022; 32: 142–8.