Prediction of The Energy Required for Ho:YAG Laser Lithotripsy of Urinary Stones

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Purpose: In this study, we aimed to find a more accurate predicting constant value of energy per mm^{3}xHounsfield Unit (HU) to ablate urinary stones by endoscopic stone treatment.

Material And Methods: The files of 142 patients who underwent rigid or flexible ureteroscopic laser lithotripsy in our clinic between December 2018 and March 2020 were evaluated retrospectively. Total energy administered for the ablation of the stone was obtained from the registry of the Ho:YAG laser and recorded to the follow-up forms. The constant value was calculated for each stone, and the final mean value was figured out by calculation of the mean of all constant values.

Results: The study was conducted with 142 patients; 102 males and 40 females. The mean age of the population was 46.61 ± 14.58 years. The number of stones was 1.27 ± 0.67. The mean constant value of energy needed per mm^{3}xHU for urinary stones was 22.87 milliwatt.

Conclusion: This study was conducted to report a predictive constant value and is the very first study evaluating the energy prediction per mm^{3}xHU. The data of the study showed that the constant value is 22.87 mW/mm^{3}xHU. Urologists may estimate the required energy and plan the surgery according to the outcomes of the study. As a future aspect of our study, the constant value may represent predictive information about the time and accuracy of the operation.

Keywords: laser lithotripsy; urolithiasis; energy; ureteroscopy

INTRODUCTION

The laser lithotripsy has been used as a treatment option for urinary stone disease for three decades after the development of the holmium: yttrium–aluminium–garnet (Ho:YAG) laser[1]. Pulsed lithotripter characteristic of Ho:YAG laser made it possible to use these devices for removal of urinary stones. Early on, pneumatic or ultrasonographic lithotripters were used during ureteroscopy. However, the development of flexible ureteroscopes and more powerful laser fibers allowed surgeons to access and remove the stones regardless of stone size and location in the urinary tract. A new treatment option has been popular because of these technologic developments: flexible ureteroscopy (FURS). Nowadays, there are emerging studies evaluating Thulium-fiber lasers (TFL) as lithotripters for urinary stones[2].

Although percutaneous nephrolithotomy (PNL) is recommended as the gold standard treatment option for renal stones greater than 20 mm, current studies in the literature report stone-free rates as high as PNL provides[3]. Besides, FURS has lower complication rates, including fewer high-grade complications compared to PNL. So, there is an increasing trend towards FURS for urinary stone treatment even for larger stones. However, there are still some controversial points when to opt for FURS. In the literature, it has been reported that the complication rate increases when the stone burden or density is high or the operation time is extended. Several studies stated that the complication rates surged when the Hounsfield Unit (HU) of the stone increased, which also induced the extended operation time[4-7].

It is crucial to decide which surgical procedure would be better for both patient and surgeon, and which one provides better success. Thus, choosing the treatment modality should be based on achieving high success rates and low complication rates. To accomplish these, calculating the estimated operation time and the need for energy can provide a foresight if FURS procedure is the right option.

In the literature, some studies evaluated the required energy for urinary stone removal regarding the size and the density of the stone[8-11]. In this study, we aimed to find a more accurate predicting constant value of energy per mm^{3}xHU to ablate urinary stones by ureterorenoscopy.

MATERIAL AND METHODS

The files of 142 patients who underwent endoscopic laser lithotripsy in our clinic between December 2018 and March 2020 were evaluated retrospectively, after the approval from the institutional review board (Decision Number: 2020-KAEK-189_2020.05.19_11). Age, gender, stone number, stone size, stone burden, stone density and stone localization were obtained from the follow-up forms. Also, all the perioperative and postop-

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erative data like operation time, stone-free status, total energy administered, complications and hospitalization time were investigated.

The patients who were between 18 and 85-year-old and did not have urinary anomaly, history of urinary tract infection or urinary surgical intervention within the last six months, DJ stent before surgery and stated as stone-free after the first procedure, were included in the study. The patients who had a urinary anomaly, history of urinary tract infection, DJ stent or urinary surgical intervention, residual stone fragments greater than 3 mm and FURS procedures in which UAS was not used were excluded.

Routine preoperative assessment tests were performed before the operation. Patients were evaluated by computerized tomography (CT). The stone size was measured as the longest diameter of the stone on the CT. The sum of all longest dimensions was recorded as the stone size in case of multiple stones. The stone burden was calculated according to the ellipsoid formula (stone volume = π*l*w*d*0.167), where length (l), width (w), and depth (d) are stone diameter measured in three axes [12]. The stone density was assessed in HU by CT. The time between starting endoscopy and end of DJ stent insertion was defined as operation time.

Intravenous first-generation cephalosporin was administered 30 minutes before the surgery for the surgical prophylaxis. All procedures were performed under general anesthesia. URS was preferred for stones in the distal, mid or proximal ureter. And FURS was the choice for renal stones. Firstly, the surgeon accessed the ureter by a 9.5 F ureteroscope (Karl Storz®, Tuttlingen, Germany) for a safe dilatation under the guidance of a guidewire. The 7.5 F ureteroscope was used to reach the stone in URS procedure. Ureteral access sheath (Elite Flex®, Ankara, Turkey) was placed in the ureter in all FURS cases. A 7.5 F flexible ureteroscope (Flex-X2®, Karl Storz, Tuttlingen, Germany) was used for FURS. A 200 µm laser fiber (Ho YAG Laser; Dornier MedTech®; Munich, Germany / Dornier Med-Tech GmbH, Medilas H20 and HSolvo, Wessling, Germany) was used for laser lithotripsy. The energy of the laser was chosen between 0.8 – 1.5 Joule and 8 – 15 Hz. At the end of the operation, a ureteral stent was placed in all patients. Operation time was defined from the beginning of cystoscopy to the end of ureteral stent placement. Stone ablation time was defined as the time between starting fragmentation and total ablation of the stone. Intraoperative data were recorded. Patients who had no complication were discharged on the first postoperative.

Total energy administered for the ablation of the stone was obtained from the registry of the Ho:YAG laser and recorded to the follow-up forms. Then, the constant value of energy per mm^3xHU was calculated according to the formula

$$k = \frac{\text{Total Energy}}{\text{Stone Burden } (mm^3) x\, Stone\ Density\ (HU)} x1000.$$

The constant value was calculated for each stone, then the mean of all constant values was given as the final mean value.

All analyses were done using SPSS 25.0 statistical software (SPSS, Chicago, USA). To describe data, frequencies and percentages or means ± standard deviations were used.

Table 1. Demographic data of patients and stone characteristics

Variable	
Gender (n=142) (%)	
Male	102 (71.8%)
Female	40 (28.2%)
The Mean Age (years) (mean ±SD)	46.61 ±14.58
Stone Number (mean ±SD)	1.27 ±0.665
Stone Size (mm) (mean ±SD)	12.70 ±6.68
Stone Volume (mm^3) (mean ±SD)	553.10 ±667.34
Stone Density (HU) (mean ±SD)	990.13 ±302.63
Stone Localization n(%)	
Upper Calyx	3 (2.1%)
Middle Calyx	9 (6.3%)
Lower Calyx	20 (14.1%)
Renal Pelvis	29 (20.4%)
Proximal Ureter	29 (20.4%)
Mid Ureter	17 (12.0%)
Distal Ureter	30 (21.1%)
Multi-Calyceal	5 (3.5%)

RESULTS

The study was conducted with 142 patients; 102 males and 40 females. The mean age of the population was 46.61 ± 14.58-year-old. The number of stones was 1.27 ± 0.665. Mean stone volume was 553.10 ± 667.34 mm^3, and the mean density of the stones was 990.13 ± 302.63 HU. Sixty-six patients had renal stones (superior calyx: 3, middle calyx: 9, lower calyx: 20, renal pelvis: 29 and multi-calyceal: 5), 76 had ureteral stones (proximal ureter: 29, mid ureter: 17 and distal ureter: 30). Mean operation time and mean stone ablation time was 58.91 ± 31.08 min and 32.08 ± 25.96 min, respectively. The demographic data and the stone characteristics were shown in **Table 1**.

Fifteen patients encountered surgical and postoperative complications. Eleven patients had hematuria which resolved with immobilization and hydration. One patient had fever exceeding 38°C for only 24 hours and resolved with antipyretics. Three patients had urinary tract infections. Although two of them cured with empiric antibiotics, one of the had urosepsis and died because of sepsis.

Mean required energy to ablate urinary stones was 11009.76 watts. The mean constant value of energy needed per mm^3xHU for urinary stones was 22.87 milliwatt (mW). The perioperative outcomes and the mean constant value were shown in **Table 2**.

DISCUSSION

The success rate of endoscopic urinary stone treatment has been increased from the introduction of flexible ureteroscopes and laser lithotripters. Thus, these instruments have been preferred for large stones. In the literature, there are several studies evaluating the success rates for the stones larger than 20 mm and reporting that FURS is safe and efficient for these stones[3,13].

There is a lack of studies evaluating the needed energy to remove the urinary stones. Regarding the impact of the stone size on the operation success, Panthier et al. evaluated how much energy required to ablate 1mm^3 of stone by laser lithotripsy and categorized the needed energy according to the stone composition. They found that calcium oxalate monohydrate stones need 35.9 ± 20 joules, cystine stones required 101.1± 47 joules and uric acid stones needed 126.2 ± 30 joules[8]. However, it is not possible to know the stone composition before

Table 2. The perioperative outcomes and the mean constant value

		Standard Deviation
The Mean Operation Time (minute)	58.91	±31.08
The Mean Flouroscopy Time (second)	13.51	±10.58
The Mean Stone Ablation Time (minute)	32.08	±25.96
The Mean Energy Required (Watts)	11009.76	±15713.73
The Mean Hospitalization time (day)	1.63	±2.28
Complications		
No	127 (89.4%)	
Fever	1 (0.7%)	
Haematuria	11 (7.7%)	
Urinary Tract Infection	3 (2.1%)	
The Mean Constant Value (milliwatt/mm3xHU)	22.87	±23.75

the operation, but a prediction can be made according to the density of the stone. In another study, Ventimiglia et al. reported that 19 J was required per mm^3 for urinary stones[14]. It was lower than our results but this variation may depend on the theory which did not consider the density of stone as a co-factor influencing the required energy. Although there are various required energy amounts reported in the literature, none of them reckoned the density of stone into calculation of the required energy. So, we conducted this study in another point of view on how much energy is needed to ablate per mm^3xHU. The results showed that 22.87 mW of energy is required per mm^3xHU to ablate urinary stone.

FURS and Ho:YAG laser lithotripsy were mostly studied for renal stones, especially for lower caliceal stones [15]. Current studies have shown that FURS is almost safe and efficient as other procedures. Bozkurt et al. evaluated the patients with 15-20 mm lower pole renal stones and reported 89.2% stone-free rate (SFR) after the first session of FURS. The SFR was increased to 94.6% with additional procedures[16]. In another study, it is reported that the SFR three months after the surgery was 82.1% and comparable to PNL for the stones up to 20 mm[17]. On the other hand, in a meta-analysis, it is stated that SFR varies between 73.9% and 93.3% for stones greater than 20 mm[18]. In this study, only the patients who were stone-free after the first session were included in the study.

Recent studies identified the stone size and volume as an independent predictive factor affecting the success of ureteroscopy[19-22]. Yamashita et al. stated that increasing stone size was the only independent predicting factor for auxiliary procedures[23]. In addition, Goldberg et al. reported that SFR for FURS decreases significantly when the diameter of the stone is greater than 15 mm (24). In another study, staged operation is recommended in order to achieve success if the stone size is ≥ 20 mm (25). The other influence of stone size and volume is on the complication rate of FURS. It is reported that larger stones (>30mm) were associated with higher complication rates[26]. Another factor affecting the success rate is the density of the stone. There are studies evaluating the correlation between the density of the stone and the success. All showed that the SFR increases when HU of the stone decreases[27,28].

Operative time can predict the operation difficulty and complexity. On the other hand, stone burden and density are correlated with the operation time, which affects the stone-free rate. A retrospective analysis reported that larger stone volume and higher HU increase the operation time; thus, the complication rate soars up[29]. Also, it is stated as a predicting factor for higher complication rates[30]. Sorokin et al. reported that stone volume has the most substantial impact on operation time [6]. Mekayten et al. stated that more time is necessary for dusting the stone those had higher density even for more powerful laser lithotripters[10]. In this study, mean stone volume and density were 553.10 ± 667.34 mm^3 and 990.13 ± 302.63 HU, respectively. The mean operation time in our study was 58.91 ± 31.08 minutes. The complication rate was 10.6% and similar, as stated in the literature.

It is crucial to predict how much energy is needed to remove the complete stone and how long will the operation take before the surgery. As a result of this, the surgeon and the patient can discuss the operation time and estimated complication and success rate even for another treatment option or possible second procedure. This is beneficial when choosing the operation method and also satisfies both sides. Multiplying the stone volume and density and division of the constant value of energy will give the estimated energy needed for stone removal. By calculating the estimated energy, the urologist can decide the pulse energy and frequency of the Ho;YAG laser lithotripter and can calculate the estimated time to dust the stone. Although correlation analysis has not been performed, this constant value can be used as a predictive tool and will give the chance to select another treatment option if the operation takes longer.

However, this study has limitations. Retrospective nature and the small amount population of the study are the major limitations. Also, we did not categorise the stones according to the composition.

CONCLUSIONS

Estimating the need of laser energy and time to dust the whole stone would facilitate the urologists' work, so a constant value stating the requirement of laser energy should be used as a predictive tool for urinary stone treatment. Thus, this study was conducted to report a predictive constant value and is the very first study evaluating the energy prediction per mm^3xHU. The data of the study showed that the constant value is 22.87 mW/mm^3xHU. Urologists may estimate the required energy and plan the surgery according to the outcomes of the study. As a future aspect of this study, the constant value may represent predictive information about the time and accuracy of the operation. Further prospective randomised trials with more patient population should be performed to verify the outcomes of this study.

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