

Ho:YAG Laser Settings in RIRS for Low-Density Renal Pelvis Stones

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ABSTRACT

The aim of this study was to compare dusting-like and fragmentation-like holmium:yttrium-aluminum-garnet laser settings during retrograde intrarenal surgery in patients with renal pelvis stones measuring 10–20 mm and Hounsfield units <1000. This retrospective study included 182 adult patients undergoing retrograde intrarenal surgery for solitary renal pelvis stones between January 2022 and November 2025. Patients were treated using either low-energy/high-frequency (0.4 J × 45 Hz) or high-energy/low-frequency (1.5 J × 12 Hz) laser settings. Both protocols delivered comparable total power (18 W). No active basket extraction was performed. The primary outcome was stone-free status at 4–6 weeks, defined as residual fragments ≤2 mm on low-dose computed tomography.

A total of 182 patients were included (0.4 J × 45 Hz: n=89; 1.5 J × 12 Hz: n=93). Baseline characteristics were comparable. Median operative time was shorter in the low-energy/high-frequency group (55 [45–65] min vs 61 [52–70] min, $p<0.001$). Laser activation time was longer in this group (26.0 [24.0–28.0] vs 24.0 [21.0–29.0] min, $p<0.001$). Stone-free rates at 4–6 weeks were higher (93.3% vs 86.0%, $p=0.048$). Complication rates were low and similar (4.5% vs 6.5%, $p=0.748$).

In this retrospective cohort, low-energy/high-frequency Ho:YAG laser settings were associated with significantly shorter operative time and higher early stone-free rates at 4–6 weeks postoperatively, suggesting that pulse modulation—rather than total power alone—may influence lithotripsy efficiency in low-density stones.

Keywords: Dusting; Fragmentation; Hounsfield unit; Ho:YAG laser; Retrograde intrarenal surgery; Renal pelvis stone

Introduction

Urinary stone disease is a common condition with substantial recurrence rates and remains a significant global health burden. Its epidemiology varies according to geographic, environmental and metabolic factors (1). Non-contrast computed tomography (NCCT) is the current reference imaging modality for urolithiasis, enabling accurate assessment of stone size, location and density, which are critical parameters in treatment selection (2). Among these, stone density measured in Hounsfield units (HU) has emerged as a clinically relevant predictor of stone composition and fragility, influencing treatment response across different modalities such as extracorporeal shock wave lithotripsy and endourological interventions (3–5). With advances in flexible ureteroscopy and laser technology, retrograde intrarenal surgery (RIRS) has become a first-line treatment option for renal stones ≤2 cm [6]. The primary aim of RIRS is to achieve

maximal stone clearance while minimizing morbidity; however, procedural efficiency and success are influenced by several stone-related factors including size, location and density (7). Two principal laser lithotripsy strategies are commonly employed during RIRS: dusting, which generates fine particles for spontaneous clearance, and fragmentation, which produces larger fragments requiring active retrieval. Fragmentation may facilitate immediate stone clearance, whereas dusting has been associated with shorter operative time and reduced need for auxiliary instruments (8, 9). Emerging evidence suggests that stone density plays a role in laser–stone interaction and fragmentation dynamics, indicating that HU may serve as a useful parameter for tailoring lithotripsy strategy (10). Despite this, the optimal laser approach for lower-density stones remains unclear. This issue is particularly relevant in renal pelvis stones measuring 10–20 mm with HU <1000, where fragmentation behaviour and treatment efficiency may differ according to laser energy settings. Data specifically addressing the

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optimal lithotripsy strategy in this subgroup remain limited.

This study aims to isolate the effect of pulse energy–frequency modulation under matched power conditions in a homogeneous cohort of low-density renal pelvis stones. We hypothesized that, under matched total power conditions, low-energy/high-frequency Ho:YAG laser settings would be associated with shorter operative time and higher early stone-free rates than high-energy/low-frequency settings in patients with low-density renal pelvis stones.

Materials and Methods

Study Design and Population: This retrospective, single-center study included adult patients who underwent unilateral retrograde intrarenal surgery (RIRS) for solitary renal pelvis stones between January 2022 and November 2025. The study protocol was approved by the local ethics committee (Decision No. GOKAEK/2026-03/09; approval date: 06 March 2026) and conducted in accordance with the Declaration of Helsinki. To minimize variability related to calyceal anatomy, stone relocation, and deflection-dependent laser efficiency, the analysis was restricted to stones located exclusively in the renal pelvis.

Inclusion Criteria Included: age ≥ 18 years; solitary renal pelvis stone; stone size between 10–20 mm; stone density < 1000 HU; Ho:YAG laser RIRS performed; and available postoperative imaging at 4–6 weeks.

Exclusion criteria included: multiple stones; bilateral procedures; thulium fiber laser use; active urinary tract infection; pregnancy; significant ureteral stricture; and missing imaging or key perioperative data.

Preoperative Assessment: All patients underwent standardized evaluation including urinalysis, urine culture, and routine laboratory testing. Stone size and density were assessed using non-contrast CT. Stone density was calculated as the mean HU value obtained from three non-overlapping regions of interest placed within the stone on the largest axial CT slice. Only stones with attenuation values < 1000 HU were included.

Surgical Technique: The procedures were performed by multiple experienced endourologists at our tertiary referral center under general anesthesia using the same digital flexible ureteroscope, the same ureteral access sheath, and the same Ho:YAG laser system (Jena, Germany)

with a 272- μm fiber in long-pulse mode throughout the study period. To isolate the effect of laser energy settings on lithotripsy behaviour, no active basket extraction was performed in either group. Lithotripsy strategy was determined according to the individual surgeon's routine practice and intraoperative clinical judgment in this non-randomized retrospective cohort. No predefined protocol or objective criteria were used for treatment allocation because of the retrospective nature of the study. Because no active stone retrieval was performed, the terms "dusting-like" and "fragmentation-like" refer to the predominant pattern of stone disintegration produced by each laser setting rather than to a specific retrieval strategy. Accordingly, fragmentation in this study reflects macroscopic stone breakage without basket extraction. To minimize performance bias, both laser settings were selected to provide similar total power output (18 W), thereby isolating the impact of pulse energy and frequency modulation on stone ablation behavior.

Patients were treated using one of two predefined Ho:YAG laser settings with matched total power output (18 W):

- (1) Low-energy/high-frequency ($0.4 \text{ J} \times 45 \text{ Hz}$) and
- (2) High-energy/low-frequency ($1.5 \text{ J} \times 12 \text{ Hz}$).

The high-energy/low-frequency protocol was intended to promote macroscopic stone breakage without active basket extraction. Postoperative DJ stenting was performed according to institutional practice.

Outcomes: The primary outcome was stone-free status at 4–6 weeks. Stone-free status was defined as residual fragments ≤ 2 mm. The ≤ 2 mm threshold was selected based on prior evidence suggesting that fragments of this size are clinically insignificant and unlikely to require secondary intervention. Residual fragments were measured as the largest diameter on postoperative CT.

Secondary outcomes included operative time, laser activation time, and postoperative complications classified according to the Clavien–Dindo system.

Follow-up: Postoperative stone-free assessment was performed at 4–6 weeks using low-dose non-contrast CT. Postoperative CT images were evaluated by board-certified radiologists as part of routine clinical practice, independently of the study. Only patients with available postoperative CT imaging were included in the final analysis.

Statistical Analysis: Statistical analyses were performed using IBM SPSS Statistics for Windows,

Version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean $\pm$ standard deviation or median (interquartile range) according to data distribution, which was assessed using the Shapiro–Wilk test. Normally distributed variables were compared using Student's t-test, while non-normally distributed variables were analyzed using the Mann–Whitney U test. Categorical variables were presented as number (percentage) and compared using the χ^2 test or Fisher's exact test, as appropriate. All tests were two-sided, and a p-value <0.05 was considered statistically significant. No propensity score matching was performed; however, baseline variables were comparable between groups.

Results

A total of 182 patients met the inclusion criteria and were included in the final analysis, comprising 89 patients treated with the 0.4 J $\times$ 45 Hz setting and 93 patients treated with the 1.5 J $\times$ 12 Hz setting.

Baseline characteristics: Baseline demographic and clinical characteristics were comparable between the two groups. No statistically significant differences were observed in age, body mass index, stone size, or stone density (all $p > 0.05$). Similarly, sex distribution and rates of preoperative ureteral stenting did not differ significantly. Preoperative laboratory parameters, including serum creatinine, hemoglobin, C-reactive protein, and white blood cell count, were also similar between groups (Table 1).

Perioperative and Postoperative Outcomes: Postoperative double-J stent placement rates were high and comparable between groups (97.8% vs 98.9%, $p=0.615$). Overall complication rates were low and did not differ significantly between the 0.4 J $\times$ 45 Hz and 1.5 J $\times$ 12 Hz groups (4.5% vs 6.5%, $p=0.748$). All complications were limited to Clavien–Dindo grade I–II events. Perioperative laboratory changes, including postoperative creatinine, hemoglobin, CRP, and WBC levels, were also comparable between groups (Table 1).

Laser-related Parameters and Treatment Efficacy: Laser activation time was longer in the 0.4 J $\times$ 45 Hz group compared with the 1.5 J $\times$ 12 Hz group (26.0 min [IQR 24.0–28.0] vs 24.0 min [IQR 21.0–29.0], $p<0.001$).

Operative time was shorter in the 0.4 J $\times$ 45 Hz group (55 [45–65] min) compared with the 1.5 J $\times$ 12 Hz group (61 [52–70] min, $p<0.001$).

The need for reintervention was numerically lower in the 0.4 J $\times$ 45 Hz group (6.7% vs 14.0%), although this difference did not reach statistical significance ($p=0.176$).

Stone-free outcomes: Stone-free status at 4–6 weeks was numerically higher in the 0.4 J $\times$ 45 Hz group compared with the 1.5 J $\times$ 12 Hz group (93.3% vs 86.0%, $p=0.048$).

Discussion

In this retrospective, single-center cohort of renal pelvis stones measuring 10–20 mm with HU <1000 , low-energy/high-frequency Ho:YAG laser settings were associated with shorter operative time and higher early stone-free rates, while complication rates remained similar between groups. These findings suggest that pulse modulation—rather than total power alone—may represent a clinically relevant and modifiable intraoperative parameter influencing lithotripsy efficiency, particularly in low-density stones.

Flexible ureteroscopy has become one of the most commonly used approaches for renal stones ≤ 2 cm, largely due to its minimally invasive profile and favorable recovery. Meta-analytic evidence supports its role as an effective alternative to other modalities in appropriately selected stone burdens (11). In parallel with broader adoption, attention has shifted from whether to perform fURS/RIRS to how to optimize intrarenal lithotripsy strategy, particularly the balance between dusting and fragmentation with active extraction (9, 12–14).

Two intrarenal strategies are classically described: (i) fragmentation into several-millimeter pieces with subsequent basketing, and (ii) dusting into fine particles intended for spontaneous passage (9, 12, 15). Fragmentation with basketing theoretically maximizes visual stone clearance and enables stone sampling for metabolic evaluation, and its safety and efficacy have been reported in multiple clinical series (9, 12–14). Conversely, dusting may reduce instrument exchanges and dependence on basket extraction, potentially shortening operative time and lowering consumable-related costs (15, 16). However, comparative literature has been mixed regarding whether dusting compromises stone-free outcomes.

In the EDGE prospective multicenter experience, basketing was associated with higher stone-free rates compared with dusting, while overall complication profiles were similar (9). Other studies also highlight that reported differences in stone-free rates can depend on the definition of stone-free status (e.g., thresholds such as <3 mm vs no fragments) (17). In our study, stone-free status was assessed at 4–6 weeks using low-dose NCCT, and we defined stone-free as ≤ 2 mm

residual fragments, which strengthens comparability and likely reduces misclassification relative to ultrasound or plain radiography.

Importantly, our cohort was restricted to HU <1000, a clinically relevant threshold frequently used to characterize “softer” stones and to anticipate lithotripsy behavior. Registry-level data (e.g., FLEXOR) support the clinical relevance of HU for intra- and postoperative outcomes in RIRS, and contemporary evidence syntheses also emphasize HU as a practical predictor in stone treatment decision-making (10, 18). Moreover, several scoring systems for predicting RIRS outcomes include HU among their core inputs, and external validation work supports its role in predicting stone-free status (19-22). By minimizing HU heterogeneity, our study allowed a more focused evaluation of pulse modulation under matched total power conditions.

Operative time is clinically meaningful not only for efficiency but also because prolonged procedures have been associated with higher infectious risk after ureteroscopy in prior work (23, 24). In our cohort, operative time was shorter in the 0.4 J × 45 Hz group (median 55 [45–65] min) compared with the 1.5 J × 12 Hz group (median 61 [52–70] min; $p < 0.001$). Fragmentation may induce retropulsion and stone mobility, necessitating repeated re-targeting and potentially prolonging overall operative time. This difference is directionally consistent with reports suggesting that dusting can reduce operating time in some settings (15, 16). Mechanistically, high-energy fragmentation may generate larger mobile fragments that require repeated re-targeting and manipulation, whereas lower-energy/high-frequency settings can sustain continuous ablation into fine debris, which may be particularly advantageous for renal pelvis stones where access is generally less constrained than in lower pole anatomy.

Although laser activation time was slightly longer in the low-energy/high-frequency group, continuous fine ablation likely reduced the need for retargeting and fragment repositioning, which may explain the shorter overall operative time. This effect may be particularly pronounced in stones with HU <1000, which tend to fragment rapidly and exhibit limited displacement during laser interaction. Furthermore, aspiration-assisted irrigation may have facilitated continuous clearance of fine dust particles, which could help preserve endoscopic visibility and reduce stone displacement. Together with the lower retropulsion profile of low-energy pulses, this may

have allowed more stable targeting and faster completion of lithotripsy.

Although dusting is often discussed in the context of spontaneous passage, residual fragments remain clinically relevant because they can lead to symptoms and future interventions. The natural history of residual fragments after ureteroscopy shows that a proportion of patients ultimately require secondary procedures, and EDGE registry analyses suggest that intervention risk is not trivial (25). In our study, the reintervention rate numerically favored 0.4 J × 45 Hz, but did not reach statistical significance, which may reflect limited power for this endpoint or the relatively high stone-free rates overall in a HU-selected cohort.

Finally, our data reinforce that patient- and stone-related factors—particularly stone burden and physical characteristics—remain central to outcome prediction. Prior studies have demonstrated associations between higher Hounsfield unit (HU) values and longer operative times and/or larger residual fragments, supporting the role of CT-derived density metrics in procedural planning (4, 26). By specifically focusing on renal pelvis stones with HU <1000, our study provides a more targeted clinical message: in lower-density stones with favorable anatomy, laser pulse modulation toward low-energy/high-frequency settings can enhance procedural efficiency and early stone clearance.

From a clinical standpoint, these findings support tailoring intraoperative laser settings according to stone density. In such cases, low-energy/high-frequency configurations represent an efficient and clinically applicable strategy without increasing complication risk, thereby contributing to a more individualized and optimized RIRS approach.

Limitations: This study has several limitations. First, its retrospective design and single-center setting may introduce selection bias and limit the generalizability of the findings. Although the cohort was restricted to renal pelvis stones with HU <1000, residual confounding from unmeasured patient- and stone-related factors cannot be completely excluded. Second, lithotripsy strategy was determined according to each surgeon's routine clinical practice and intraoperative clinical judgment rather than random allocation, and no propensity score matching was performed. Although all procedures were performed by experienced endourologists using a standardized surgical setup, differences in surgeon experience, operative technique, and other unmeasured procedural factors may have influenced the observed outcomes. Although

Table 1: Baseline and Perioperative Characteristics of Patients Undergoing RIRS For Renal Pelvis Stones With HU <1000

Variable	0.4 J × 45 Hz (n=89)	1.5 J × 12 Hz (n=93)	p-value
Age, years	46.97 ± 17.22	47.02 ± 15.97	0.982
BMI, kg/m ²	25 (23–30)	26 (24.15–28)	0.773
Stone size, mm	12.1 ± 2.7	12.8 ± 3.6	0.14
Stone density (HU)	750 (690–890)	850 (610–920)	0.636
Male, n (%)	44 (49.4)	42 (45.2)	0.668
Preoperative ureteral stent, n (%)	26 (29.2)	23 (24.7)	0.607
Postoperative double-J stent, n (%)	87 (97.8)	92 (98.9)	0.615
Preoperative creatinine, mg/dL	0.82 (0.67–0.94)	0.84 (0.66–0.93)	0.751
Postoperative creatinine, mg/dL	0.84 (0.66–0.94)	0.85 (0.70–0.95)	0.636
Preoperative hemoglobin, g/dL	15.00 (14.00–15.50)	15.30 (13.90–15.80)	0.288
Postoperative hemoglobin, g/dL	14.60 (13.20–15.70)	15.10 (13.50–15.68)	0.468
Preoperative CRP, mg/L	2.91 ± 3.67	3.46 ± 4.81	0.489
Postoperative CRP, mg/L	1.00 (0.00–3.00)	1.00 (0.00–6.00)	0.124
Preoperative WBC, ×10 ³ /μL	8.10 (6.10–9.60)	7.65 (6.35–9.00)	0.244
Postoperative WBC, ×10 ³ /μL	7.70 (6.70–9.10)	7.50 (6.30–8.70)	0.344
Operative time (min)	55 (45–65)	61 (52–70)	<0.001
Complications, n (%)	4 (4.5)	6 (6.5)	0.748
Laser activation time, min	26 (24–28)	24 (21–29)	<0.001
Need for reintervention, n (%)	6 (6.7)	13 (14.0)	0.176
Stone-free rate, n (%)	83 (93.3)	80 (86.0)	0.048

postoperative CT images were evaluated independently by board-certified radiologists as part of routine clinical practice, a formal blinded imaging review protocol was not implemented. Third, cost analysis and consumable utilization were not evaluated. Finally, follow-up was limited to early stone-free assessment, and long-term outcomes were not assessed.

Prospective studies focusing on HU-defined renal pelvis stone subgroups are warranted to validate these findings. The borderline statistical significance observed for stone-free rates should be interpreted cautiously, and extrapolation to other stone locations or higher-density stones should be avoided.

Despite these limitations, our findings provide clinically relevant insight into laser setting optimization during RIRS. In renal pelvis stones measuring 10–20 mm with HU <1000, low-

energy/high-frequency Ho:YAG laser settings were associated with shorter operative time and higher early stone-free rates without increasing complication risk. These results indicate that pulse modulation—rather than total power alone—may be a key determinant of lithotripsy efficiency and support a more tailored intraoperative laser strategy.

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Disclosure

Conflict of interest: The authors declare no conflict of interest.

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obtained from the local ethics committee (Decision No. GOKAEK/2026-03/09; approval date: 06 March 2026), and the study was conducted in accordance with the Declaration of Helsinki.

Informed consent: Not applicable.

Registry and the registration no. of the study/trial: Not applicable.

Animal studies: Not applicable.

Data availability: Data are available from the corresponding author upon reasonable request.

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