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Outcomes of ureteroscopy and laser fragmentation using a 60 W MOSES laser: a 3-year prospective study from a University Teaching Hospital

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Abstract

Introduction: Modulated optics enhancement system (MOSES) holmium lasers use "pulse modulation" to increase the efficacy of laser lithotripsy. As the clinical evidence on the efficacy of 60 W holmium laser with MOSES technology is scarce, we analyzed the outcomes of patients treated with this laser at our institution.

Methods: A total of 96 consecutive patients with urinary stones (72 renal stones and 24 ureteral stones) were treated with the 60 W MOSES laser from 2019 until 2022 and were included in our analysis. Patient data and outcomes were prospectively collected, and analysis was performed regarding patient demographics, stone parameters, as well as stone-free rate, operating time, length of stay, and perioperative and postoperative complications.

Results: With a median age of 55 (IQR: 35–69.25) years, the male:female ratio was 53:43. The median stone size was 12 mm (IQR: 7–19), with a mean number of urinary stones of 1.82 (SD ± 1.4). While 36 (35%) patients were pre-stented, a ureteral access sheath was inserted in 36 (37.5%) patients. The median operative time was 44 min (IQR: 22.5–59.5), and 63 (65.5%) patients received postoperative stenting. Perioperative complications (all Clavien ⩽ II complications) were observed in 5 (5.2%) patients (four urinary tract infections and one acute urinary retention), and after the first procedure, 90 (93.8%) patients were stone-free. The median length of hospital stay was 1 day (IQR: 1–1).

Conclusion: This study demonstrated that the 60 W MOSES laser was safe and efficient for the treatment of urinary stones with high stone-free rates and a small risk of minor complications. More studies with larger cohorts are necessary in the future to confirm our results.

Keywords: endourology, kidney calculi, lasers, MOSES, ureteroscopy

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Introduction

Kidney stone disease (KSD) is a prevalent condition affecting a substantial proportion of the adult population globally. With an increasing incidence attributed to factors such as global warming and lifestyle changes, the need for effective surgical interventions remains critical. A significant challenge in KSD management is the high rate of recurrence, with over 50% of patients experiencing a second episode within a decade of their initial stone event. Such recurrent episodes often necessitate repeated surgical procedures, posing an elevated risk of chronic kidney disease development and imposing substantial health and socioeconomic burdens.[1,2]

In recent years, advancements in laser technology have provided new opportunities for improved stone fragmentation during lithotripsy.[3,4] While the holmium:YAG laser has traditionally been

regarded as the gold standard, emerging innovations such as the modulated optics enhancement system (MOSES) have shown promising results.

The MOSES technology employs pulse modulation, dividing the laser's energy into two pulses. The initial pulse generates microbubbles in the surrounding water, while the subsequent pulse targets the stone directly, facilitating enhanced fragmentation while minimizing stone migration.[5] In vitro studies have demonstrated the potential of MOSES technology to enhance lithotripsy efficacy compared to conventional holmium:YAG lasers.[6,7]

Although some clinical studies have reported similar outcomes in terms of stone-free rates (SFRs), operating time, safety, and efficacy between MOSES technology and traditional lasers, the existing evidence base is still limited.[8–13] As such, further research is warranted to comprehensively evaluate the efficacy and safety of the MOSES laser technology in a larger patient population. As the clinical evidence on the efficacy of 60 W holmium laser with MOSES technology is scarce, we analyzed the outcomes of patients who underwent ureterorenoscopy for kidney and ureteral stones treated with this laser at our institution.

Methods

Our ureteroscopy outcomes were registered as an audit (6901) with the hospital's "Clinical Effectiveness and Audit" department.

Study design and patient selection

A retrospective analysis of prospectively collected data was performed. The study included 96 consecutive patients who underwent ureteroscopy and laser lithotripsy (URSL) for stone treatment using a 60 W Lumenis holmium:YAG laser with MOSES technology from 2019 to 2022. Inclusion criteria were patients aged >18 years, undergoing semi-rigid and/or flexible ureteroscopy, with either a single stone or multiple stones, and no congenital or acquired anatomical abnormality of the urinary system. No selection criteria were applied based on a previously known biochemical composition of the stones. Exclusion criteria were patients aged <18 years, patients with transplanted kidneys or congenital or acquired anatomical abnormalities, staghorn stones, infected obstructed kidneys, or urosepsis. Patients with complete documentation of relevant parameters were included. Patient demographics, stone location, size, density, SFRs, operating time, length of hospital stay, and peri/postoperative complications were documented.

Preoperative non-contrast CT (CTKUB) was performed for diagnostic imaging. Patients with positive preoperative urine culture received appropriate treatment based on sensitivity analysis. All patients underwent pre-assessment in an anesthesiologic-led clinic. No patient included in the cohort had recently undergone shock wave lithotripsy (SWL).

Surgical technique

All procedures were conducted by a single surgeon. A rigid URS was performed using a 4.5 or 6F Wolf or Storz semi-rigid ureteroscope, following initial cystoscopy and safety wire placement. A flexible ureteroscope (Storz FlexX2) was used for flexible ureteroscopy. Lithotripsy was performed with the 60 W Lumenis holmium laser with MOSES technology. A 200–350 µm laser fiber was used for lasertripsy. Operative time was measured from the insertion of the cystoscope (start) to the removal of the scope at the end of the procedure. Laser settings used for lithotripsy in the ureter were below 10 W of overall power and lithotripsy in the kidney could reach up to 25 W overall power. No additional device to prevent stone retropulsion was used.

The laser settings were maintained at 0.4–1 J and 20–40 Hz, utilizing dusting and pop-dusting techniques. Fragments were extracted using a nitinol basket (Ngage, Cook Medical, Bloomington, IN, USA or Dakota, Boston Scientific Corporation, USA). A ureteral access sheath (UAS) was placed at the surgeon's appraisal (9.5 F/11.5 F or 12 F/14 F Cook Flexor UAS). A 6F ureteral stent was inserted postoperatively if necessary. SFR was defined as endoscopically stone-free or ⩽2 mm fragments on postoperative imaging, which was a plain X-ray (radio-opaque stones) or USS (radiolucent stones) at 2–3 months post-surgery. Complications were classified according to the Clavien-Dindo classification system.

Data were collected using Microsoft Excel 2016 (Microsoft, Redmond, WA, USA). Statistical analysis was conducted using SPSS version 26 26 (IBM, Armonk, NY, USA). The independent *t*-test, Mann–Whitney *U* test, and Chi-squared test were used, with a *p*-value of <0.05 as significant.

Results

The study population consisted of 96 consecutive patients with urinary stones, including 72 (75%) cases of renal stones and 24 (25%) cases of ureteral stones. The median age of the patients was 55 (IQR: 35–69.25) years, with a male-to-female ratio was 53:43.

The median stone size in our overall cohort, ureteric stones, and renal stones were 12 mm (IQR: 7–19), 9 mm (IQR: 7–14), and 13 mm (IQR: 7.1–19), respectively, with a mean number of urinary stones for overall cohort, ureteric stones, and renal stones of 1.82 (SD ± 1.4), 1.75 (SD ± 1.8), and 1.84 (SD ± 1.2), respectively. While 36 (37.5%) patients were pre-stented, a UAS was inserted in 36 (37.5%) patients. The median operative time was 44 min (IQR: 22.5–59.5), and 63 (65.6%) patients received postoperative stenting. Perioperative complications were observed in five patients (5.2%), all Clavien-Dindo ⩽ II complications. Four patients experienced postoperative urinary infections treated with oral antibiotics and one patient experienced postoperative urinary retention needing a temporary catheter. Following the first procedure, 90 patients (93.8%) were stone-free. All patients with ureteric stones (100%) and 66 (91.7%) patients with renal stones were stone-free. The median length of hospital stay for the patients was 1 day (IQR 1–1) (Table 1). During the included follow-up period, no evidence of ureteral stenosis has been reported.

In a subgroup analysis of lower pole stones ($n = 34$) and stones in the other renal locations ($n = 38$), the use of UAS was done in 16 (47.1%) and 14 (36.8%), postoperative stent in 26 (76.5%) and 23 (60.5%), respectively, with a SFR of 85.3% and 97.4% ($p = 0.64$) and a complication rate of 8.5% for the lower pole group.

Stone density was not routinely reported from the preoperative CT scan of patients submitted to URS. The stone composition was as follows: calcium oxalate ($n = 70$, 72.9%), calcium phosphate ($n = 18$, 18.8%), struvite ($n = 4$, 4.2%), cystine ($n = 1$, 1%), and uric acid ($n = 3$, 3.1%).

Discussion

This prospective single-center surgeon study investigates the outcomes of ureteroscopy and laser fragmentation using a 60 W holmium:YAG MOSES laser over a period of 3 years from 2019 to 2022. To our knowledge, this is the first study reporting on the outcomes of laser lithotripsy with 60 W holmium:YAG with MOSES technology, which could be considered as a mid-power laser, in the wide variety of available lasers of different power systems.

Holmium:YAG laser has changed treatment trends in KSD, shifting trends toward ureteroscopic stone management whilst achieving higher stone-free rates. In the light of extensive research, it has received various modifications over the past decades.[3,14] Clinical studies have shown higher energy settings (0.6–1.2 J) to be better for stone fragmentation and extracting techniques,[15] whereas lower energy settings were shown to be more suitable for dusting urinary stones rendering them very small and eliminating the need for stone extraction.[16] A faster stone fragmentation or dusting can be achieved using higher laser frequency settings (80–100 Hz); however, higher frequencies were demonstrated to cause more retropulsion.[17]

Recently introduced MOSES technology utilizes the combination of two laser pulses. The first pulse generates a vapor cavity paving the way to deliver a more efficient second pulse to the stone.[18] In preclinical in vitro and in vivo studies, MOSES technology was shown to reduce stone retropulsion and increase ablation volume.[6,7] The 60 W holmium:YAG MOSES laser combines the MOSES technology with the advantages of a mid-power laser. Our study shows laser lithotripsy with a 60 W holmium:YAG MOSES laser to be a safe and efficient choice in the treatment of urinary stones.

Following the first procedure, the overall SFR was 93%, 91.7% for renal stones, and 100% for ureteric stones. One of the largest study cohorts that has been published in recent years was the study from the CROES Group. Of the 11,885 patients that were included, 1852 (15.6%) had only renal stones and 8676 (73.0%) had only ureteral stones, with an overall SFR of 85.6%. Our study showed a higher SFR with a much lower complication rate. The comparably lower SFR in the CROES study is most probably due to the heterogeneous nature of this study. Altogether, 114 centers with different lithotripsy modalities and multiple surgeons were involved in this study. On the other hand, our single-center study was conducted by one experienced stone surgeon.[19]

Table 1. Patient demographics, stone characteristics, and outcomes of ureteric and renal stones.

Variables	MOSES 60 W overall (n = 96)	Ureteric stones (n = 24)	Renal stones (n = 72)	
Age (median, IQR)	55 (35–69.25)	56 (51–65.75)	52.5 (31–71.75)	$p = 0.12$
Males	53 (55.2%)	15 (62.5%)	38 (53.5%)	$p = 0.44$
Females	43 (44.8%)	9 (37.5%)	34 (46.5%)	$p = 0.44$
Previous endoscopic procedures	26 (27.1%)	7 (29.2%)	19 (26.4%)	$p = 0.52$
Recurrent urinary tract infection	15 (15.6%)	1 (4.2%)	14 (19.4%)	$p = 0.17$
BMI	28.4 (24–32.9)	27.3 (24.5–31.45)	28.6 (23.9–34.1)	$p = 0.34$
Ureteral stones	24 (25%)	24 (25%)	—	
Proximal	8	8	—	
Mid	5	5	—	
Distal	11	11	—	
Renal stones	72 (75%)	—	72 (75%)	
Pelvis	13	—	13	
Upper pole	13	—	13	
Mid pole	12	—	12	
Lower pole	34	—	34	
Pre-operative stent	36 (37.5%)	14 (58.3%)	22 (30.6%)	$p = 0.015$
Stones number (median, IQR)	1 (1–2)	1 (1–1.75)	1 (1–2.75)	$p = 0.4$
Total stone size (median, IQR)	12 (7–19)	9 (7–14)	13 (7.1–19)	$p = 0.47$
Multiple stones	39 (40.6%)	6 (25%)	33 (45.8%)	$p = 0.07$
Operative time (median, IQR)	44 (22.5–59.5)	45 (7.5–57.75)	40 (25–60)	$p = 0.29$
Ureteral access sheath	36 (37.5%)	6 (25%)	30 (41.7%)	$p = 0.14$
Postoperative stent	63 (65.6%)	14 (58.3%)	49 (68.1%)	$p = 0.38$
Length of stay (median, IQR)	1 (1–1)	1 (1–1)	1 (1–1)	$p = 0.28$
Complications	5 (5.2%)	2 (8.3%)	3 (4.2%)	$p = 0.43$
Stone-free	90 (93.8%)	24 (100%)	66 (91.7%)	$p = 0.14$

Holmium:YAG MOSES laser was shown to be a safe modality in our study. Only five patients in our study presented with perioperative complications, all ⩽Clavien-Dindo II. Four patients experienced postoperative UTI that were treated with antibiotics and one patient went into retention after the procedure, leading to the placement of a urethral catheter, which is not standardly placed postoperatively in our institution.

Although in vitro studies have demonstrated less retropulsion and high efficacy in lithotripsy, clinical studies are still warranted. Recently, Ibrahim et al. compared the fragmentation efficiency of the conventional regular mode of 120 W holmium laser to the MOSES contact mode on a stone simulator.[7] Moreover, they compared the degree of stone retropulsion between both modes, a Likert scale from 0 (no retropulsion) to 3

(maximum retropulsion). They demonstrated a significant reduction in stone retropulsion with MOSES mode (mean Grade 2.5 vs Grade 1; $p < 0.01$). Similarly, a shorter procedural time during fragmentation (13.9 vs 9.1 min; $p \leqslant 0.01$) and dusting (9.3 vs 7.1 min; $p \leqslant 0.01$) was observed with the MOSES mode.[7] Similarly in another in vitro study, Elhilali et al. demonstrated a significant reduction in retropulsion when using the MOSES mode. In light of these initial findings, the MOSES laser was postulated to facilitate shorter operating times.[6] Although in vitro studies have shown that laser lithotripsy with MOSES technology shows lower retropulsion and higher efficiency, evidence that these results translate into clinical practice is still lacking. In our study, the median operative time was 44 min with a median stone size of 15 mm.

Pulse modulation determines the interaction between the laser energy and the stone. Beyond the selection of short and long-pulse (LP) modalities available for the holmium laser, the MOSES technology combines two sub-pulses to increase the delivery of laser energy to the stone surface. Pulse shapes and profiles of standard and MOSES Holmium laser have been widely characterized in in vitro studies, and the subsequent clinical implications exposed. Of note, a lower retropulsion and a less energetic water streaming have been observed when the LP modality is used, due to the longer pulse and lower peak power. On the other hand, both LP standard holmium laser and MOSES holmium laser show similar average peak power and total pulse width, thus resulting in similar retropulsion and ablation efficiency.[20] Despite these encouraging laboratory data, robust clinical evidence about the superiority of MOSES technology over standard Holmium laser is still lacking. The peak power of the thulium fiber laser (TFL) demonstrates a longer and rectangular shape with a lower peak power compared to the holmium laser. In controlled in vitro conditions, lithotripsy on BegoStones has proved that retropulsion for the holmium:YAG LP and MOSES modes were similar and lower than that for the SP mode, but higher compared to TFL.[21]

Despite this, one of the clinical advantages of MOSES technology could lie in lower intra-renal temperatures during lithotripsy compared to other holmium laser modalities, thus preventing thermal injuries caused by prolonged lithotripsy for bigger stones.[22] Finally, pooled evidence from a recent systematic review and meta-analysis published by Riveros et al.,[23] comparing outcomes of standard versus MOSES lithotripsy on 1205 patients from six studies, confirmed that MOSES technology showed better lasing time and stone ablation speed compared to standard Holmium laser, whereas results were similar in terms of fragmentation time and SFR.

The primary objective of this pilot study was to provide insights into our initial experience with the 60 W holmium:YAG MOSES laser and show that it is a safe and efficient choice for laser lithotripsy. However, this study has some limitations. The study included consecutive patients without specific selection criteria. Furthermore, it is important to note that the assessment of lithotripsy duration, quality of life, and cost was not conducted in this study.[24,25] Further randomized controlled trials with comparator groups and stone volume are warranted to validate and substantiate our preliminary findings. Perhaps the role of mid-power lasers also needs to be acknowledged in the guidelines.[26]

Conclusion

Our study demonstrates that the use of the 60 W MOSES laser for the treatment of urinary stones is safe and efficient. The high stone-free rates and small risk of perioperative complications observed in this cohort support the efficacy of the 60 W MOSES laser in achieving successful stone fragmentation. Further studies with larger cohorts are warranted to confirm and validate our findings.

Declarations

Ethics approval and consent to participate

Audit committee approval was obtained and all patients consented for the procedure.

Consent for publication

All patients consented to the study and signed a consent form.

Author contributions

Victoria Jahrreiss: Data curation; Project administration; Writing – original draft.

Francesco Ripa: Data curation; Formal analysis.

Bhaskar Somani: Conceptualization; Supervision; Writing – review & editing.

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Competing interests
The authors declare that there is no conflict of interest.

Availability of data and materials
None.

Research involving human participants and/or animals
This review involves human participants and our study was registered as an audit (6901) with the hospital "Clinical Effectiveness and Audit" department.

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