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Role of low- *versus* high-power laser in the treatment of lower pole stones: prospective non-randomized outcomes from a university teaching hospital

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Abstract

Introduction: Ureteroscopy and laser stone fragmentation [flexible ureteroscopy and laser lithotripsy (FURSL)] has risen over the last two decades. Laser technology has also evolved over the time, shifting from low- to high-power lasers with the addition of MOSES technology that allows for 'dusting and pop-dusting' of stones. The aim of the study was to look at the outcomes of FURSL in lower pole stones (LPS) using low- and high-power lasers.

Patient and Methods: In this study, we compared the outcomes of low-power holmium laser (group A, 20 W) and high-power holmium laser (group B, including both 60 W MOSES integrated system and 100 W lasers) for all patients with LPS treated with laser lithotripsy. Data were collected for patient demographics, stone location, size, pre- and postoperative stent, length of stay, complications and stone free rate (SFR).

Results: A total of 284 patients who underwent FURSL procedure for LPS were analysed (168 group A, 116 group B). Outcomes showed that compared with group A, group B had a higher SFR (91.6% *versus* 96.5%, $p = 0.13$) and shorter operative time (52 *versus* 38 min, $p < 0.001$). The median length of stay was <24 h in all groups (day-case procedures). The complication rate was comparable between the two groups but with more infectious complications ($n = 7$) noted in group A compared with group B ($n = 3$) ($p = 0.53$).

Conclusion: Compared with low-power laser, the use of high-power laser for LPS significantly reduced the use of ureteral access sheath (UAS), postoperative stent and procedural time. Although non-statistically significant, the SFR was higher in the high-power group even for relatively larger stone sizes, which was also reflected in a reduction of sepsis-related complication rates with these lasers.

Keywords: Urolithiasis, Laser, Ureteroscopy, Lasertripsy

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Introduction

The prevalence of urolithiasis is increasing in Europe and worldwide, with an increasing trend of intervention over the last two decades.[1,2] With an increase in the lifetime prevalence, females are now almost as equally affected as males.[3] Due to the anatomy of the lower pole, which is below the ureteropelvic junction, stones frequently tend to form and aggregate in the lower pole group of calices. With the infundibulo-pelvic angle (IPA), lower pole stones (LPS) are more difficult to access and hence have a lower stone free rate (SFR) often necessitating secondary therapeutic procedures.[4] Careful consideration of IPA and infundibular length (IL) needs to be taken into account to predict successful stone removal in these cases.[5] Flexible ureteroscopy and laser lithotripsy (FURSL) of renal stones is now an established treatment for LPS.[6] While holmium laser is the gold standard of laser lithotripsy, controversy still exists on the optimal laser energy and settings, and uncertainty around the power needed to ablate a specific size and composition of stones.[7] Hence, there is a heated debate to determine whether a low- or high-power laser system is better.

With technological advancements and improved training, FURSL has been increasingly used to treat stones >2 cm, achieving optimal outcome in terms of SFR and reduced complication rates when compared with percutaneous nephrolithotomy (PCNL).[8] A recent study seems to show that laser power might not affect the FURSL outcomes.[9] Newer holmium lasers are equipped with a pulse-modulating system called MOSES™ technology. This technique delivers the laser energy in an asymmetric manner such that an initial bubble is created through which the remainder of the energy can then travel, without being absorbed by surrounding water.[10] Other recent technologies have been introduced in the field of endourology such as the thulium fibre laser (TFL) and novel mechanical lithotrites combining ultrasonic energy, ballistic energy and suction capability; however, the latter are more used in PCNL.[11]

High-power holmium laser has already shown its superiority in terms of treating large renal stones and its outcomes have been described in a recent paper.[12] Conversely, a recent review has found that there is an equivalence in outcomes irrespective of the power of laser devices, but these are also dependent on the stone characteristics and laser settings used.[13,14]

In this prospective non-randomized study, we wanted to compare the outcomes of FURSL for LPS using low-power (20 W laser) with high-power (60 W MOSES and 100 W laser) laser systems.

Materials and methods

Our ureteroscopy outcomes were registered as an audit (6901) with the hospital 'Clinical Effectiveness and Audit' department. All patients had given preoperative informed consent for their participation. While consecutive patients with LPS were included, patients with isolated non-LPS and ureteric stones were excluded. Patients with LPS with multiple other renal stones were also included.

All procedures were performed by a single surgeon (B.K.S.), and the outcomes were collected for consecutive patients prospectively and recorded in our database for patient demographics, preoperative assessment, stone characteristics and multiplicity, procedural details, laser system and settings, SFR, length of stay (LoS) and complication rates. Patients underwent FURSL for LPS using a 20 W holmium laser (group A) and high-power laser systems (group B) using a 60 W Holmium MOSES integrated laser or 100 W holmium laser (all lasers from Lumenis, Ltd., Yokneam, Israel). The outcomes were analysed by a third party (T.H.) not involved in these procedures. Patients in groups A and B had their procedures between March 2012 and December 2016, and January 2017 and December 2020, respectively. The surgeon had already performed over 400 ureteroscopies prior to this study. The LoS was defined from completion of URS to the patients' discharge, with 'day case' defined as patients who went home the same day as their surgery.[15] Data were recorded in a Microsoft Excel 2018 (Microsoft, Redmond, WA, USA) and analysed using SPSS, version 28 (IBM, Armonk, NY, USA). The Kolmogorov–Smirnov test was used to assess the normality of distribution. The Mann–Whitney *U* test was used for continuous variables, and the chi-square test and Fisher's exact test were used for categorical variables. A p value of <0.05 was considered statistically significant.

Preoperative assessment

The stone diagnosis was made on a non-contrast computerized tomography scan of the kidneys, ureters and bladder (CTKUB) for adults and ultrasound scan (USS) for paediatric patients (<16 years). While patients had preassessment in dedicated anaesthetist-led clinics, patients with positive preoperative urine culture were treated as per the microbiological results.

Surgical technique

A protocol-based procedure was performed under a general anaesthetic. The presurgical briefing was done as per the World Health Organization (WHO) checklist with planning for antibiotic prophylaxis, venous thromboembolism (VTE) prophylaxis and any anticipated surgical or anaesthetic issues.

The procedure followed a standardized step-by-step technique starting with a cystoscopy and safety wire placement, followed by the insertion of a 4.5 F or 6 F Wolf or Storz semi-rigid ureteroscope over a working wire. Based on surgeon discretion and expected difficulty of the case, a ureteral access sheath (UAS) was used (9.5 F/11.5 F or 12 F/14 F Cook Flexor UAS).

A flexible ureteroscopy (Storz FlexX2 or FlexXC) and laser (Lumenis, Ltd., Yokneam, Hakidma, Israel) stone treatment was then done. The laser setting used was a maximum of 0.4–1 J and 10–18 Hz for group A, and 0.4–1 J and 20–50 Hz for group B. With high-power lasers (group B), 'Pop dusting' technique was used.[12] Fragments were retrieved using Cook Ngage stone extractor (Cook Medical, Bloomington, IN, USA), and a 6 F ureteral stent was placed postoperatively when indicated, as per surgeon's discretion.

Postprocedural outcomes

SFR was defined as complete clearance of stones endoscopically and ⩽2 mm fragments on postoperative imaging, usually in the form of plain radiograph for radiopaque stones and USS for radiolucent stones. If the situation was unclear and ambiguity remained and patients had symptoms, a CT scan was done for clarification. All intra- and postoperative complications were recorded, and the latter were classified as per the Clavien–Dindo classification system. Postoperative stent was removed routinely with flexible cystoscope and grasper in an outpatient setting.

Results

A total of 284 patients who underwent FURSL procedure for LPS were analysed (168 group A, 116 group B – 39 using 60 W MOSES and 77 using 100 W laser; Table 1). The mean age was 53 and 47 years for groups A and B, respectively. Details on stone location, size, and pre- and postoperative stent usage are shown in the table. The cumulative stone sizes were 9.6 ± 2.4 and 13.5 ± 8.3 mm for groups A and B, respectively.

While all patients had LPS, stones in multiple renal locations were present in 57% and 48% in groups A and B, respectively, with UAS was used in 54% and 35% of patients across the groups ($p < 0.001$). Although the SFR was higher in group 2, this was not significant (91.6% *versus* 96.5%, $p = 0.13$). The mean operative time was significantly shorter for group 2 (52 *versus* 38 min, $p < 0.001$). The median LoS was 0 days in all groups.

The complication rates between the two groups were 4.7% ($n = 8$) and 4.3% ($n = 5$) in groups A and B, respectively ($p = 0.87$), with 11 of these being Clavien I/II complications. The two Clavien III complications (one in each group) were sepsis that needed temporary intensive care unit (ICU) admission. Notably, there were more infectious complications in group A (4.1%) compared with group B (2.6%); however, this difference was not statistically significant ($p = 0.53$). No intraoperative incident or complications was reported in any of the groups.

Discussion

Meaning of the study

Our study shows how a high-power laser can reduce the operative time which translates into a reduction in infectious complications and urosepsis, in addition to treating larger stones as compared with low-power lasers. This is one of the first studies in literature looking at the role of different laser power settings for the treatment of LPS. Our results were achieved with 'dusting and pop-dusting' techniques using the higher power laser (Table 1). Despite treating significantly larger stones ($p < 0.001$), the use of UAS was significantly lower ($p = 0.001$) and the postoperative stent usage was also significantly lower ($p < 0.001$).

Comparison of our study with published literature

Our study contrasts the findings from a recent review which reported no difference in outcomes using different laser power settings.[13] The systematic review analysed 22 non-randomized studies with a total of 6403 patients. Their results show that high-power laser has an increased lithotripsy speed, but SFR was similar to the low-power laser. Also, no difference in terms of complication rate was observed between these two laser groups. Other studies by Aldoukhi *et al.* on BegoStones showed a better fragmentation rate, with smaller fragments generated with high-power laser, when the laser fibre was in contact with the stone.[16] The same group has also demonstrated how MOSES pulse modulation can result in more fragmentation even with non-contact laser lithotripsy.[17] MOSES technology was also

Table 1. Outcomes of FURSL in group A (20 W) and group B (60 + 100 W) lasers.

	Low power Group 1 (20 W) Group A	Group 2 (60 W)	Group 3 (100 W)	High power (60 + 100 W) Groups 2 + 3 (combined) Group B	*p* value (low power *versus* high power) Group A *versus* group B
Number of patients	168	39	77	116	
Age (mean ± SD) (range)	53.94 ± 16.03 (18–85)	44.64 ± 24.68 (3–83)	48.70 ± 17.32 (14–80)	47.34 ± 20.08 (3–83)	$p = 0.009$
Gender (male:female)	107:61	21:18	49:28	70:46	$p = 0.619$
Stone location (LP: LP + other renal stone)	72 (42.9%): 96 (57.1%)	20 (51.3%): 19 (48.7%)	40 (51.9%): 37 (48.1%)	60 (51.7%): 56 (48.3%)	$p = 0.141$
Preoperative stent cases (%)	53 (31.5%)	11 (28.2%)	25 (32.5%)	36 (31.0%)	$p = 0.927$
Postoperative stent cases (%)	157 (93.5%)	23 (59%)	55 (71.4%)	78 (67.2%)	$p < 0.001$
UAS (%)	91 (54.1%)	15 (38.4%)	26 (33.7%)	41 (35.3%)	$p = 0.001$
Mean cumulative stone length (mm)	9.69 ± 2.47	13.09 ± 7.95	13.83 ± 8.65	13.58 ± 8.38	$p = 0.001$
Total number of stones (mean ± SD) (minimum–maximum)	1.70 ± 1.14 (1–14)	1.90 ± 1.07 (1–5)	1.96 ± 1.26 (1–8)	1.94 ± 1.19 (1–8)	$p = 0.253$
Operative time (min)	52.02 ± 27.90	47.40 ± 24.54	35.45 ± 21.64	38.46 ± 22.88	$p < 0.001$
Length of stay (median)	0 days (0–64)	0 days (0–2)	0 days (0–3)	0 days (0–3)	$p = 0.065$
Stone free rate	154 (91.6%)	37 (94.8%)	75 (97.4%)	112 (96.5%)	$p = 0.136$
Repeat procedure	4 (2.4%)	1 (2.6%)	1 (1.3%)	2 (1.7%)	NS ($p = 1$)
Overall complications *(infectious complications)*	8 (4.7%) Sepsis ($n = 4$) UTI ($n = 3$) Pain ($n = 1$) *7 (4.1%)*	1 (2.6%) Urinary retention ($n = 1$) *0*	4 (5.2%) Sepsis ($n = 3$) Pain ($n = 1$) *3 (3.9%)*	5 (4.3%) Sepsis ($n = 3$) Pain ($n = 1$) Urinary retention ($n = 1$) *3 (2.6%)*	$p = 0.870$ *$p = 0.53$*
Clavien–Dindo grade	Grades I–II-- 7 Grade III – 1	Grades I–II –1 Grade III – 0	Grades I–II – 3 Grade III – 1	Grades I–II – 4 Grade III – 1	

FURSL, flexible ureteroscopy and laser lithotripsy; SD, standard deviation; UAS, ureteric access sheath; UTI, urinary tract infection; LP, lower pole; NS, not specified.

considered superior compared with non-MOSES FURSL, with a lower fragmentation and procedural time, and less retropulsion, according to a recent randomized study.[18] A previous study with MOSES high-power laser also found that most surgeons ranked this new technology as better or much better than normal holmium laser lithotripsy.[19] One of the key features that translates into better clinical outcomes with MOSES power modulation *in vivo* and *in vitro* is the reduced retropulsion rates that in turn seems to speed up the stone ablation time.[20–22]

A similar study to ours was performed by an Israeli group.[23] They retrospectively compared patients who underwent FURSL with 120 W MOSES laser *versus* 20 W laser, demonstrating that the higher power laser achieved better stone fragmentation, reducing the operative time by half. They also noted that lasing efficacy could be dependent on stone density. On comparing the two lasers, high-power laser had a more constant lasing time while the low-power laser took longer with more dense stones. This confirmed the findings that stone dusting with high-power laser is faster, when compared with the standard low-power laser especially in hard stones. Similarly, a group from the United States compared a cohort of patients treated with Lumenis Pulse 120 W holmium laser system using either MOSES or regular mode. The use of MOSES effect in their series did not significantly change the procedural time or fragmentation/dusting time. Moreover, there were no differences in complications or SFR.[24] Wang *et al.* also compared MOSES contact mode and regular dusting mode during FURSL. They found a shorter laser ablation, better efficacy with overall shorter operative time with the former.[25] These outcomes are similar to the ones achieved by Pietropaolo *et al.* who compared low-power laser (20 W) with mid-power MOSES laser (60 W), finding faster stone lithotripsy rate related to a reduction in operative time with 60 W laser, with lower number of patients thereby needing a repeat procedure.[26]

Limitations of the study

Our study is based on a retrospective analysis of data collected prospectively. Although it was a retrospective study in that regard, data were collected for consecutive patients by independent operators in order to avoid bias, and the presence of a single operating surgeon with prior experience of over 400 ureteroscopies ensures learning curve stability. However, randomized controlled studies should be performed to adequately compare different types of lasers in order to eliminate possible confounders. The absence of standardized follow-up and variable SFR assessment that included all imaging modalities could also be a potential bias on SFR outcomes. The use of CT scans has led to a better evaluation of the clinically insignificant residual fragments and potentially should be considered for all patients.[27]

Areas of future research

The holmium:yttrium–aluminum–garnet (Ho:YAG) laser has been used for over 20 years in endourology and has been extensively studied; the pulse modulation technology appears to give benefit to the overall procedure. Lately TFL was introduced for stone treatment, which seems more promising in view of being able to generate very high pulse frequency.[28] Both technologies are expected to continue to play a large role in laser lithotripsy. However, even though laser lithotripsy is considered a safe procedure, adequate training and precautions are mandatory to avoid harmful adverse events to the patient or the operators.[29]

Ureteroscopy-related infectious complications are related to operative times, and efforts must be made to minimize them.[30] Endourology theatre can cause workplace-related injury to the operators due to exposure to radiation- and laser-related issues. These hazards can be mitigated by implementing several evidence-based safety measures, such as protective glasses, that can decrease the risk of eye injury from laser exposure.[31] Sepsis related to FURSL is mainly connected not only to the patient preoperative morbidity but also to intraoperative variables. Long operative time and increased intrarenal pressure can indeed increase the risk of postoperative urosepsis with requirement of intensive care support and rarely can lead to death of the patient.[32,33]

Our study shows how a high-power laser can reduce the operative time, which translates in reduction in infectious complications and urosepsis. In future, randomized trials are necessary to compare different lasers and settings, to identify and compare outcomes, including SFR, postoperative complications and quality of life of patients. Perhaps studies also need to compare the cost of laser machines and fibres, with the cost savings related to reduced operative time and the need for secondary procedure to achieve the stone free status.[34,35]

Conclusion

Compared with low-power laser, the use of high-power laser for LPS significantly reduced the use of UAS, postoperative stent and procedural time. Although non-statistically significant, the SFR was higher in the high-power group even for relatively larger stone sizes, which was also reflected in a reduction of sepsis-related complication rates with these lasers.

Ethics approval and consent to participate

Our ureteroscopy outcomes were registered as an audit with the University Hospital Southampton 'Clinical Effectiveness and Audit' department. Registered audit code was 6901, with name 'retrospective and prospective outcome of endourological procedures'. All patients had given preoperative informed consent for this research purpose.

Author contribution(s)

Amelia Pietropaolo: Data curation; Investigation; Methodology; Writing – original draft; Writing – review & editing.

Mriganka Mani: Data curation; Software; Validation.

Thomas Hughes: Formal analysis; Visualization.

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Availability of data and materials

Anonymised data and materials are available on request.

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