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Impacted ≥ 10-mm pelvic ureteric stone treatment: laser lithotripsy alone or in combination with pneumatic lithotripsy—a prospective, comparative study

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Abstract

Background: The aim of this study is to evaluate the outcome of ureteroscopic lithotripsy of combined pneumatic and laser versus laser lithotripsy alone for the treatment of impacted pelvic ureteral stones. Ninety patients with impacted stones 10 mm or more were selected and divided into two equal groups. The combined group included patients who treated by pneumatic lithotripsy (PL) and laser lithotripsy (LL), while those in the laser group were treated by LL alone via retrograde semirigid ureteroscopy. Exclusion criteria included urinary tract infection, radiolucent stones, ipsilateral concurrent stone, previous ureteral surgery, urinary tract anomalies, musculoskeletal deformities, renal failure and pregnancy. Any stone retropulsion or any residual stone detected 1 month postoperative was considered failure.

Results: The stone-free rate was 88.8% and 91.1% for laser and combined groups, respectively, which was statistically insignificant ($p \geq 0.05$). Operative complications were 11.11% versus 4.4% for laser and combined groups, respectively, which is significant statistically ($p < 0.05$). No ureteral perforation and no stricture were developed in the combined group, while one perforation and two strictures were developed in the laser group. The DJ stenting and second session lithotripsy requirements were 64.4% versus 51.1% and 15.5% versus 8.8% for laser versus combined group, respectively, and each was statistically significant.

Conclusion: When treating impacted stones, combining PL to LL can decrease the complication rate, DJ stenting and second session lithotripsy requirement, while preserving laser fragmentation capabilities.

Keywords: Pelvic ureter stones, Impacted, Combined, Pneumatic lithotripsy, Laser lithotripsy

1 Background

The first treatment of choice for proximal ureteral stone, according to the European Association of Urology guidelines, is ureterorenoscopy (URS) if the stone is larger than 10 mm [1]. Although ESWL is a noninvasive modality, it is unlikely to be successful for impacted ureteral stones because of the lack of natural expansion space around the stones, so this situation is better managed by ureteroscopy [2]. Even more, impacted ureteral stones are enveloped in inflamed, edematous mucosa which impeded stone exposure that makes disintegration more difficult. These make patients with impacted ureteral stones to be considered at risk for less effective initial treatment and a higher complication rate [3]. Advancement has refined the ureteroscopes as well as lithotripter. Currently, the most commonly used are pneumatic lithotripsy (PL) and holmium:yttrium–aluminum–garnet (Ho:YAG) laser lithotripsy (LL) which has been improved the success rate while decreasing the complications [4].

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PL is preferred by many urologists because of its relatively low cost, low maintenance and high success rates. So they consider it comparable to laser in spite of a high rate of upward stone migration [5, 6]. On the other hand, there is a trend in favor of using LL owing to advantages on fragmentation and flexibility [7]. Daily practice and literature show that the prevalence of impacted ureteral stones is high; however, the literatures that focused on the outcomes of ureterolithotripsy for impacted stones are limited and stone impaction is a neglected topic in the guideline [8]. This work has been designed to evaluate the safety and efficacy of combined PL and LL compared to LL alone for the treatment of impacted proximal ureteric stones.

2 Methods

From February 2015 to December 2018, 90 consecutive patients with radiologic and endoscopic signs of impacted pelvic ureteric stones 10 mm or more were prospectively selected. Patients were divided into two equal groups. Patients were allocated to one of the two treatment groups, laser only (laser group, 45 patients) or combined pneumatic and laser (combined group, 45 patients), based on the order of their presentation. Exclusion criteria included uncontrolled urinary tract infection, uncontrolled coagulopathy, radiolucent stones, concurrent ipsilateral renal or ureteric stone, previous ipsilateral ureteric surgery, urinary tract anomalies, musculoskeletal deformities, renal failure or pregnancy. The ethics committee approved the study protocol, and informed consents were obtained from all patients. Patients were evaluated by full clinical history, urinalysis and urine culture, serum creatinine, blood urea nitrogen and coagulation profile. Radiologic evaluation was carried out by plain X-ray of kidney–ureter–bladder (KUB), ultrasonography of abdomen and pelvis (USG) and/or computed tomography. Any stone located in the ureter between the inferior borders of sacroiliac joint till the ureteric orifice was accepted as a pelvic ureter. Stone size was represented by the greatest stone diameter, and stone surface area was calculated by multiplying the stone length by the stone width in mm as measured on plain X-ray or non-contrast computed tomography (NCCT). Stone-free status was considered when there was no fragment by imaging study either early on the first postoperative day or late, 1 month postoperative. Impaction was considered when the stone was immobilized for at least 1 month, there was a sudden cutoff in the contrast media at the stone level on imaging study and there was a failure or reasonable difficulty in bypassing the stone by the guidewire.

All patients had negative urine culture and received IV antibiotics with the induction of general anesthesia and the procedures were done, while the patients were in lithotomy position under c-arm control. All procedures were done using semirigid URS of 8 Fr distal tip (Wolf Inc., Germany). The PL probe of 0.8 mm was activated under 2.5 atoms in either continuous or single pulse mode. Ho:YAG laser was used for stone fragmentation (LUMENIS, Versa Pulse Power Suite. 100 W) via 200 or 360-μm SlimLine laser fiber (LUMENIS). The laser device was adjusted to 0.2–0.8 joules/pulse with a frequency rate 3–16 Hz. In the combined group, the main role of PL was to induce stone disimpaction by fragmenting and separating the stone part that was adherent to ureteral mucosa and deliver the stone fragments out of its mucosal bed. Then the rest of the stone bulk is fragmented by LL. In both groups, the goal was to break the stone into particles less than 3 mm to increase the likelihood of spontaneous passage. At the end of the procedure, either open tip ureteric catheters were kept for 24–48 h or 6 Fr double-J stent kept for 4–6 weeks was fixed. Generally, DJ stenting was used to enhance stone fragment passage and facilitate ureteral mucosal healing. Second session lithotripsy was indicated when the procedure was early terminated because of bleeding causing red vision or development of significant ureteric injury. Failure was considered when there was a stone that migrated upward to proximal ureteric part or the kidney or the presence of a stone fragment of any size on imaging study 1 month postoperatively. Lithotripsy time was measured from first to last fire of the used lithotripsy devise, while operative time is the time of the whole procedure from the cystoscopy till fixation of Foley's catheter, and when two sessions of lithotripsy were attempted, the average time was calculated. Postoperatively, patients were assessed every 3 months for 1 year regarding the development of hydronephrosis and stricture by USG and enhanced CT-KUB with coronal format when indicated. Data of each group were analyzed and compared by Statistical Package for the Social Sciences (SPSS for Microsoft Windows, version 23), and p value was considered statistically significant if < 0.05.

3 Results

Patients' demographics and stone characters are shown in Table 1. The laser group and the combined group were uniform regarding age, gender, stone measurements and stone characters. Table 2 summarizes the operative and postoperative data, outcomes and complications. In terms of stone-free rate (SFR), early SFR was encountered in 62.2% (28 out of 45 patients) and 57.7% (26 out of 45 patients), while the late SFR was increased to 88.8% (40 out of 45) and 91.1% (41 out of 45 patients) for laser group and combined group, respectively, which was statistically insignificant when $p \geq 0.05$. Failure was

Table 1 Demographic data and stone characters

	Laser group	Combined group	*p* value
Patient number	45	45	–
Age (mean ± SD, years)	51 ± 9.7	49 ± 11.4	0.348
Male/female	30/15	28/17	–
BMI (mean ± SD)	26.95 ± 1.31	27.14 ± 1.42	–
Laterality (Rt/ Lt)	20/25	18/27	–
Largest stone diameter (mean ± SD, mm)	12.8 ± 1.1	13.1 ± 1.4	0.460
Stone area (mean ± SD, mm^2)	110 ± 32.7	116 ± 28.8	0.449
Hounsfield unite (mean ± SD)	965 ± 280	978 ± 266	0.589
Duration of symptoms (months)			
1–2	40 (88.8%)	39 (86.7%)	0.310
˃ 2	5 (11.2%)	6 (13.3%)	0.328
Hydronephrosis			
Mild	6 (13.3%)	5 (11.1%)	0.328
Moderate	17 (37.8%)	19 (42.2%)	0.463
Severe	22 (48.9%)	21 (46.7%)	0.496

SD standard deviation

Statistically significant = $p < 0.05$

Table 2 Operative and postoperative data, and outcome

	Laser group	Combined group	*p* value
Early stone-free rate	28/45 (62.2%)	26/45 (57.7%)	0.615
Late stone-free rate	40/45 (88.8%)	41/45 (91.1%)	0.780
Failed patients			
Stone retropulsion	2/45 (4.4%)	2/45 (4.4%)	–
Residual fragment	3/45 (6.6%)	2/45 (4.4%)	0.644
Double-J stenting	29/45 (64.4%)	23/45 (51.1%)	0.043
Basket stone retrieval	17/45 (37.7%)	18/45 (40%)	0.711
Lithotripsy time (mean ± SD, min)	15.5 ± 12.2	17.3 ± 7.2	0.781
Operative time (mean ± SD, min)	40.7 ± 26.3	43.2 ± 21.6	0.632
Second session URS lithotripsy	7/45 (15.5%)	4/45 (8.8%)	0.048
Hospital stay (mean ± SD, h)	46.6 ± 15.8	41.4 ± 16.3	0.647
Intraoperative complications	5/45 (11.11%)	2/45 (4.4%)	0.038
Bleeding-caused procedure termination	1 (2.2%)	1 (2.2%)	
Mucosal laceration	3 (6.6%)	1 (2.2%)	
Ureteral perforation	1 (2.2%)	0	
Postoperative complications	6/45 (13.3%)	4/45 (8.8%)	0.047
Fever	2 (6.6%)	2 (4.4%)	
Hematuria for ˃ 3 days	1 (2.2%)	1 (2.2%)	
Urosepsis	1 (2.2%)	1 (2.2%)	
Stricture ureter	2 (4.4%)	0	

SD standard deviation

Statistically significant = $p < 0.05$

considered due to stone retropulsion which was reported in two patients (4.4%) in each group, and all of them had associated severe hydroureteronephrosis. In the laser group, one out of two patients underwent ESWL for 9-mm stone particle that was retropulsed to upper ureter, and the second patient underwent flexible URS and LL for 7-mm stone which had been retropulsed to the lower calyx with unfavorable anatomy. In the combined group, one patient with a retropulsed stone fragment 0.4 mm in lower calyx was responded well to conservative measures, and the last had retropulsed upper ureter 0.7-mm stones which had successful ESWL. Failure due to residual stones was encountered in three (6.6%) and two (4.4%) patients in laser and combined groups, respectively. In the laser group, two out of three patients had 4-mm residuals which were treated successfully by ESWL, while the last had 3-mm asymptomatic residual which responded to expulsive medical treatment. In the combined group, the first patients had 4-mm fragment which responded to ESWL, while the second had 3- and 5-mm residuals; however, he required an auxiliary URS because of failure of the expectant treatment. Stone basket was used in 37.7% and 40% of the patients in laser and combined groups, respectively, which was statistically insignificant ($p \geq 0.05$). Double-J stent fixation was used in 29 patients (64.4%) and 23 (51.1%) of patients in laser and combined groups, respectively, which was statistically significant ($p < 0.05$). In the laser and combined groups, the lithotripsy duration (mean ± standard deviation) was 15.5 ± 12.2 and 17.3 ± 7.2 min, while the operative duration was 40.7 ± 26.3 and 43.2 ± 21.6 min, respectively, and each was statistically nonsignificant ($p < 0.05$).

In terms of operative complications, the laser group had a significantly higher complication rate than the combined group, 11.11% versus 4.4%. Mucosal laceration was more frequent in laser group than combined 6.6% versus 2.2%, and bleeding that leads to the termination of procedures because of impaired field of vision was seen in 2.2% in each of the laser and combined groups. Ureteral perforations (with no fluid leakage) were encountered only in the laser group (one patient, 2.2%). In all patients, the procedures were terminated and DJ stent was fixed for 2 to 6 weeks; then, a second session URS lithotripsy was attempted in 15.5% (seven patients) and 8.8% (four patients) of laser group and combined group, respectively, which was statistically significant ($p < 0.05$). Postoperative complications had been encountered in 13.3% and 8.8% of laser and combined groups, respectively, which was statistically significant ($p < 0.05$). Two patients in each of the laser and combined groups developed moderate-grade fever on the first and second postoperative days which was responding well to conservative treatments. Urosepsis was faced in one patient of each group, and each had associated severe hydronephrosis; however, both were responded to urinary drainage through fixing DJ stent and conservative measures. Gross hematuria lasted for more than 3 days was seen in one patient in each group; both responded well to conservative measures. The most serious complication faced during postoperative follow-up was the developed stricture, while USG-KUB revealed severe hydronephrosis in two patients in the laser group. Enhanced CT-KUB showed 12-mm-long stricture in one patient and 20 mm in the other. The former responded to ureteral balloon dilatation and DJ insertion. The later had significant mucosal laceration during URS lithotripsy where stone particles were buried in the lacerated ureteral mucosa. Minimally invasive treatment was failed, and open repair by resection and ureterovesical re-implantation was carried out. The recorded mean hospital stay for laser and combined groups was 46.6 ± 15.8 and 41.4 ± 16.3 h, respectively, which was statistically insignificant ($p \geq 0.05$).

4 Discussion

Laser and pneumatic are the most dependant lithotripters. EAU recommended Ho:YAG laser lithotripsy as a gold standard procedure for ureteroscopic intracorporeal lithotripsy because of its efficiency to fragment all stone types, ablative effect and stone dusting [9]. However, pneumatic energy is stronger and cheaper than Ho:YAG laser with minimal tissue trauma [10–13]. These different lithotripter mechanisms (mechanical vs. photothermal) affect the stone-free and upward migration. Purpurowicz and Sosnowski reported that preoperative factors such as hydronephrosis, stone size and stone location are the most commonly affecting outcomes [14]. On the other hand, De et al. emphasized that the operative factors and the technique are the more important [15]. Accordingly, combining two techniques, PL and LL not only increase the safety but also preserve the efficiency. In terms of SFR, the combined group had a nearly similar early SFR, 62.2% versus 57.7%, and the rate had been increased to 88.8% versus 91.1% for late SFR in laser and combined groups, respectively, which is statistically insignificant ($p \geq 0.05$). Hui et al. use the combined pneumatic lithotripsy and Ho:YAG laser for treating 232 patients with ureteral stones and reported 89.9% SFR which is comparably well with SFR of the combined group [16]. Degirmenci et al. compare laser and pneumatic lithotripsy for treating impacted ureteric stones and reported a distal ureteral stone-free rate of 96.8% and 91.7% for laser and pneumatic, respectively [4]. Their relatively higher SFR may be because of the smaller stone size in their series, in addition to our strict definition of stone-free status. The strategy in the combined group is to perform stone disimpaction via PL; then, laser replaces it to complete the fragmentation process. This is playing an important role in reducing not only thermal tissue injury related to laser but also stone retropulsion related to PL. Stone retropulsion met with was similar 4.4% for each group and this is comparably well with finding recorded by Degirmenci et al. who reported nearly similar retropulsion rate 6.8% (5 out of 73) and 6.4% (4 out of 62) for

Pl and LL, respectively, when treating distal impacted ureteral stone [4]. Li et al. reported 24% and 21% retropulsion rate, respectively, with insignificant statistical difference [10]; their higher rate may be related to the inclusion of patients with mid ureteric stones in addition to distal position and their relatively smaller stone size. Ureteral tissue reaction and associated limited working space due to stone impaction increase the likelihood of ureteral mucosal injuries or perforation even when gentle procedure is performed [17]. The operative complications were higher in the laser versus the combined group, 11.11% vs. 4.4%, respectively, which is statistically significant ($p \geq 0.05$); this is may reflect the safety of the heatless mechanism of pneumatic lithotripsy device when the working field is narrow due to stone impaction. No ureteral perforation was seen in combined group, but it is encountered in one patient 2.2% in the laser group. The operative complication rate is comparably well with that reported in the literature which ranged widely from 4 to 28.4% [18, 19]. Operative complications were treated by termination of the procedures as early as possible and 6 Fr DJ stent fixations which kept in place for 2 to 6 weeks; then, second session was attempted. Postoperative complication rates in laser and combined groups were 13.3% and 8.8%, respectively, which is statistically significant ($p \leq 0.05$). Brito et al. [11] reported stricture rate 4.7% after PL, and Fam et al. [17] reported a stricture rate of 7.7% after LL when treating impacted lower ureteric stones. Stricture ureter was developed in two patients (4.4%) in laser group. One had a ureteral perforation and responded successfully to ureteral balloon dilatation and DJ stent fixation, while the second had a perforation on top of extensive mucosal laceration with stone particles inevitably buried in the mucosa and was only responded to ureterovesical re-implantation. No perforation was recorded, and no stricture was detected in the combined group; the link between perforations and strictures had been observed by many authors, who commented that stricture rate is directly related to the nature of complications that developed intraoperatively, in particular ureteral perforation and lodging of the stone particles in ureteral mucosa which support our findings [11, 17].

Cevik et al. did not recommend DJ stent routinely after uncomplicated ureteroscopic lithotripsy for impacted ureteral stone [20]. In this study, we widen the indications of DJ stenting, so we fix it even when the mucosal injury is not extensive to allow ordered ureteral healing and avoid stricture development. DJ stenting was significantly less in the combined relative to laser group, 51.1% versus 64.4%, respectively, which matches the finding of Irer et al. who reported that DJ stenting was significantly lower in their pneumatic group versus laser [13]. The goal of lithotripsy process is to produce small stone chunks that can be passed out spontaneously or easily retrieved, this goal is still easily achieved in both groups, and the lithotripsy time and operative time (mean $\pm$ SD) were nearly the same in laser and combined groups (15.5 ± 12.2 vs. 17.3 ± 7.2) and (40.7 ± 26.3 vs. 43.2 ± 21.6) minutes, respectively. Many authors reported shorter lithotripsy time of pneumatic relative to laser; however, regarding the operative time the reverse was recorded because of the relative big stone chunks produced by PL which required is to be removed [21–23]. This is not the case in the current study since LL continues playing the major role in the fragmentation process with the production of stone fragments small enough to pass spontaneously. Stone impaction may be associated with bleeding from the inflamed friable mucosa that causing impaired red field of vision which occasionally necessitates early termination of the procedure, and a second session of ureteroscopic lithotripsy is indicated. Second session lithotripsy was lower in the combined than laser group, 8.8% versus 15.5%, respectively. Legemate et al. [24] reported 11.6% versus 8.1% re-treatment rate when comparing impacted versus non-impacted ureteric stones, respectively; using either PL or LL which is comparably well with our finding, Chen et al. [25] reported a higher re-treatment rate 48.5% versus 25% for PL and LL, respectively, which may be related to the proximal stone location in addition to the operator factors. The hospital stay was within the range of that reported in the literature [10, 26]. We found a nonsignificant decrease in the combined group versus laser group which may be due to fewer complications in such group; this rationale is supported by Abedi and his colleagues [26]. The limitations of this work are the small patient's number, non-uniform surgeon's experiences, the potential errors that may be introduced during stone size estimation because of two different imaging modalities (X-ray and NCCT), short duration of follow-up and non-categorized postoperative complications according to Clavien's system, and, in addition, the absence of standardization regarding the definition of the stone impaction and the stone-free status.

5 Conclusion

When treating impacted pelvic ureteric stones of ≥ 10 mm, adding PL to LL can be significantly reducing complication rates, DJ stenting and second session lithotripsy requirement while preserving laser fragmentation capabilities.

Abbreviations

PL: pneumatic lithotripsy; LL: laser lithotripsy; SFR: stone-free rate; URS: ureterorenoscopy; ESWL: extracorporeal shock wave lithotripsy; Ho:YAG : holmium:yttrium–aluminum–garnet; KUB: kidney–ureter–bladder; USG: ultrasonography; NCCT: non-contrast computed tomography; DJ: double J; SD: standard deviation.

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Authors' contributions
HA (corresponding author) contributed to the concept, data management, operative theater works, preparation and writing manuscript, revision and final shaping. AM contributed to the preparation of manuscript, data management, statistical analysis and preparation of final shape and revision. RO contributed to the data collection, preparation of manuscript and preparation of final shape adjustment and revision. AS contributed to the concept, data collection and management, preparation of manuscript and revision. TG contributed to the data management, preparation and revisions of manuscript, statistical analysis and final shape adjustment. All authors read and approved the final manuscript.

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All data generated or analyzed during this study are included in this published article.

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All procedures were in accordance with the ethical standards of our institution and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the local ethical committee of Benha University Hospital No. 126/2015. Written informed consent was obtained from all patients included in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interest.

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