A comparison of efficacies of holmium YAG laser, and pneumatic lithotripsy in the endoscopic treatment of ureteral stones

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ABSTRACT

Objective: We aimed to compare the effectiveness of holmium YAG laser and pneumatic lithotripsy in the treatment of ureteral stones.

Material and methods: A total of 216 patients who had established indications of ureteroscopy between November 2011 and June 2012 were included in this study. Patients’ files were retrospectively reviewed by dividing cases as groups that underwent pneumatic (PL) or laser lithotripsy (LL) procedures. Age, sex, stone burden and localization, duration of follow-up, operative times were evaluated. Stone-free rates were evaluated by ureteroscopical examination, postoperative scout films and ultrasonography.

Results: Group PL consisted of 109 and group LL of 107 patients. Median age was 43.93±15.94 years in Group PL and 46.15±14.54 years in Group LL. Male to female ratio, stone burden and localization were similar for both groups. Overall success rate was 89.9% in Group PL and 87.9% in Group LL, respectively (p<0.791). With the aid of additional procedures, success rate was 100% for both groups at the end of the first month. Groups were not different as for operative time, rate of insertion of an ureteral catheter and its removal time. Hospitalization period was apparently somewhat shorter in Group LL (p=0.00).

Conclusion: Pneumatic lithotripsy can be as efficacious as laser lithotripsy and be used safely in the endoscopic management of ureteral stone. In comparison of both methods, we detected no differences as to operative time, success of operation and the time to removal of the catheter, however, hospitalization period was shorter in Group LL.

Key words: Laser lithotripsy; pneumatic lithotripsy; ureteroscopy.

Introduction

Despite medical treatment, in the presence of intractable colicky pain, renal dysfunction, and persistent urinary obstruction, ureteral stones should be promptly managed. Before the year 1980, open ureterolithotomy was being performed widely, nowadays in the management of ureteral stones ESWL (Extracorporeal Shock Wave Lithotripsy) and endoscopic interventions are preferred. Endoscopic management of ureteral stones can be performed in many centers.

As effective modalities both flexible, and rigid ureteroscopy have found widespread use in 1990s, and 2000s. Gradual decrease in the caliber of ureteroscopes, improvements in the capabilities, and effectiveness of stone fragmentation systems, advancement in the design of the graspers preventing migration of stone fragments have increased the success rate of endoscopic management of ureteral stones, and contributed to its widespread application.

For intracorporeal lithotripsy, electrohydraulic, pneumatic, and laser lithotriptors can be used. Currently, pneumatic, and laser lithotriptors are most frequently used, and acceptable methods in the endoscopic management of ureteral stones. Pneumatic lithotriptor (PL) is preferred by many urologists because of its lower cost, easy instillation, and higher success rates. However higher rates of stone migration constitutes its disadvantage. Although laser lithotriptor (LL) is quite effective in the management of both proximal ureter stones, and impacted stones, it is more expensive relative to pneumatic lithotriptor.

Many studies comparing PL, and LL, as for safety, efficacy, and complications in the management of endoscopic ureteral stones are available. In addition to the studies showing
similarities between both groups\cite{8-10}, some of them reported that LL is more effective with lesser complication rates\cite{11-13}.

In our study, successive cases who had undergone intracorporeal lithotripsy in the endoscopic management of ureteral stones have been retrospectively analyzed, Groups of PL, and LL have been compared.

Material and methods

For our study required approval from the ethics committee was obtained. Medical files of the ureteral stone patients who had preoperatively given their informed surgery consent forms, and then underwent intracorporeal endoscopic lithotripsy between November 2011, and June 2012 were retrospectively reviewed. Patients with congenital renal anomalies, renal stones, history of ureteral stone operation, and/or failed ESWL, severe skeletal deformities, coagulopathies, and pregnant women were excluded from the study. Patients who had undergone pneumatic lithotripsy (PL) (n=109) or laser lithotripsy (n=107) were included in the study. Before the procedure, urine cultures were obtained, and appropriate antibiotherapy was given if bacterial growth was detected. After sterilization of urine the patients were operated. The patients received a single dose of prophylactic antibiotic, and the procedure was performed while the patient was in the lithotomy position. A 9.5 F Karl Storz brand semirigid ureteroscope was used, and-under ureteroscopic guidance a guidewire was inserted through ureter. If deemed appropriate by the surgeon, ureteral orifice was dilated with a balloon catheter before ureteral access. Use of a catheter preventing ureteral stone migration (Stone Cone, Boston Scientific/USA), DJ or ureteral stent was decided based on the intraoperative requirement.

For pneumatic lithotripsy Vibrolith Plus device (Elmed/Turkey), and 3 F pneumatic probe, for laser lithotripsy Ho:Yag Laser (Karl Storz) with 550 \( \mu \)m fiber probe, pulse frequency: 8-10 Hz, and power supply: 9.6-16 W were used. Stone areas were estimated based on their longest diameters measured on KUB scout film for opaque, and on computed-tomograms for non-opaque stones. Ureteral stones above, or below the sacroiliac joint were termed as proximal, midureter and distal ureteral stones respectively. The stones were tried to be broken in fragments less than 1 mm in size. Following lithotripsy session stone fragments were left to spontaneous passage. On postoperative 1. day stone-free state was checked with KUB films, and ultrasonograms. The patients who couldn’t pass their stones spontaneously, received medical expulsive treatment, and their stone-free state was controlled at weekly KUB films or ultrasonograms.

The patients were followed up for postoperative 3 months, and at postoperative 3. months sonograms were obtained to determine their stone-free rates. The patients were divided in two main groups (Groups PL, and LL). Each main group was also divided in 3 subgroups as patients with proximal, mid-, and distal ureteral stones. Demographic features, size, and locations of the ureteral stones, operative times, DJ use, stone-free rates on postoperative 1. days, major, and minor complications, length of hospital stay, and time to withdrawal of DJ catheter were recorded. Stone fragments smaller than 2 mm in size were considered as residual stone fragments, and stone-free state was evaluated with KUB films, and ultrasonograms obtained during ureterorenoscopy. If happened, migration of the stone into renal collecting system was also recorded.

Statistical analysis

For statistical evaluation Statistical Package of Social Sciences 15 (SPSS 15.0, Chicago, IL, USA) program was used. Concordance of data to normality of distribution was investigated with Kolmogorov-Smirnov test. For the statistical analysis of data Kruskal-Wallis analysis of variance was employed. For pairwise comparisons of data Mann-Witney U test was used. All values were expressed as mean±SD. P<0.05 was considered to be statistically significant.

Results

A total of 216 patients (female, n=66, and male, n=150; Group URS-PL, n=109; Group URS-LL, n=107) were included in our study. Mean ages of the patients in the URS-PL, and URS-LL groups were 46.15±14.54, and 46.15±14.54 years, respectively. The stones were localized in the right (n=119), and left (n=119) ureter. Stone surface areas were 56.11±23.23 mm², and 60.33±32.86 mm² in the URS-PL, and URS-LL groups respectively. Besides, in the URS-LL group, we detected proximal (29%), midureteral (23.3%) and distal (47.7%) ureter stones. A statistically significant intergroup difference was not detected as for patients’ ages, gender, stone surface, laterality, and location (Table 1).

Stone-free rates of 75, and 74.2% were achieved in the management of proximal ureter stones in the URS-PL, and URS-LL groups, respectively. The stone-free rates for midureteral, and distal ureteral stones in the URS-PL, and URS-LL groups were 85 vs. 98.4%, and 96 vs. 92.2%, respectively. Overall success rates were detected to be 89.9, and 87.9% in the URS-PL, and URS-LL group respectively (Table 2). Apart from midureteral stones stone-free rates were higher for distal, and proximal ureteral stones, being more improved in the URS-PL group without any statistically significant intergroup difference in success rates.

Total operative times were 30.31±15.03, and 34.30±19.70 min in the URS-PL, and URS-LL groups, respectively. DJ or ureteral stent was also implanted in patients in the URS-PL
Mean catheter removal times following endoscopic lithotipsies were 13.75±4.47, and 12.96±4.74 days in the URS-PL, and URS-LL groups, respectively. Any statistically significant intergroup difference was not found as for operative times, DJ or ureteral catheter insertion, and removal times. Lengths of the hospital stay was 2.08±0.7, and 1.53±0.89 days in Groups URS-PL, and URS-LL, respectively. The patients in the URS-LL group were hospitalized for a statistically significantly short times (Table 3).

Medical expulsive treatment was applied for patients who were unable to pass their stone fragments, and they were monitored at weekly intervals using KUB films, and ultrasonograms. ESWL was performed for a total of 6 (3 cases in both groups) patients with stone migration, and after employing additional interventions an overall success rate of 100% was obtained in both groups.

Major complications such as ureteral avulsion, sepsis, urinoma or hematuria requiring treatment were not observed in any patient. Stone migration was also observed in the URS-PL (n=10; 9.1%), and URS-LL (n=7; 6.5%) groups. Stone migration rates were somewhat lower in the URS-LL group without any statistically significant intergroup difference (p=0.069).

**Discussion**

In the treatment of ureteral stones with surgical indication, many treatment alternatives are available including ESWL, ureteroscopy, percutaneous antegrade ureteroscopy, laparoscopic, and open surgery. Together with technologic advances, the treatment of urinary system stone disease has undergone immense changes. In the year 1912, Young performed the first documented ureteroscopy, and inserted a cystoscope into the dilated ureter of a child with a posterior urethral valve. In 1964 Marshall delivered a fiberoptic ureteroscope through a resectoscope, and realized the first flexible ureteroscopy. The first rigid ureteroscopy was performed in 1977 by Goodman using a 9.5 F pediatric cystoscope. Since then, ureteroscopy has been evolved with a stunning speed as is the case with all minimally invasive techniques. Innovations both in ureteroscopes, and auxiliary equipments have increased the success rates of ureteroscopy, and it has been currently performed in almost all clinics. Öztürk et al. conducted a cross-sectional study in 106 urology residents, and urologists in Istanbul, and all of them reported successful application of ureteroscopy in their clinics.

During ureteroscopy, for intracorporeal lithotripsies, electrohydraulic (EHL), ultrasonic (US), pneumatic, and laser lithotriptors can be used. EHL which was discovered by Yutkin et al. in the year 1955 is the firstly developed technique. In 1985, firstly Green and Lytton used EHL in intracorporeal rigid ureteroscopy which had been hitherto employed during open renal stone surgery. The invention of laser in the world is credited to Theodore Mainman in (1960), who used a ruby laser. In 1968 Mulvaney succeeded in fragmenting a urinary system stone using ruby laser, however because of extreme warming of ruby laser during procedure, ruby laser could not be introduced into clinical use. With advancing technology, alternative laser applications with different energy sources have been performed. Currently in the urology practice Nd: YAG laser, Holmium: YAG (Ho: YAG) laser, Thulium: YAG (Tul: YAG) laser, carbon dioxide (CO₂) laser, potassium titanyl phosphate (KTP) laser, lithium triborate (LBO) laser, and diode laser have been used. Among them, currently Ho:YAG laser lithotripter is the most prevalently used ureteroscopic lithotripter in the world.
was essentially developed for prostatic surgeries, and it is used in the names of some endoscopic prostate surgeries including HoLAP (Holmium laser ablation of the prostate), and HoLRP (Holmium laser resection of the prostate). The most conspicuous advantage of Ho: YAG laser lithotriptors include its capability of disintegrating all stones irrespective of their compositions into smaller fragments when compared with other lithotriptors, and lower risk of stone migration into renal collecting system because of weaker shock waves. European Association of Urology (EAU) recommends Ho: YAG laser lithotripsy as a gold standard procedure for ureteroscopic intracorporeal lithotripsy. US lithotripsy was firstly used for the management of renal stones in 1953 by Mulvaney. Ultrasonic energy delivered through hollow steel probes induces transverse, and longitudinal vibrations which are transferred to the stone. Because of their inflexible texture, it is very difficult to use US probes in semi-rigid ureteroscopes. Still the success rate of ultrasonic lithotriptor is over 90 percent. Pneumatic lithotripsy was invented in Switzerland, and it was firstly introduced into clinical use in 1992. In this technique, compressed dry air is delivered to the probe tip, and the stone is fragmented with this created ballistic impact. Since heat is not generated during the procedure, any thermal damage is not incurred. Pneumatic lithotriptor has a markedly lower risk of perforating ureter when compared with other lithotriptors. In a study performed by Santa-Cruz et al. on experimental animal models, the authors reported that after directly sending shock waves from a pneumatic lithotriptor on ureteral wall for 6 minutes, ureteral wall perforation did not occur. In the literature rates of stone migration with pneumatic lithotriptor range between 1.6, and 17.3%, which is more frequently seen with proximal ureteral stones.

Nowadays, ureteroscopy has become the first alternative in most centers with a success rate approaching to 100 percent. EAU indicated a success rate over 90% with PL in the endoscopic treatment of ureteral stones. In our study, stone-free rates we achieved with PL were 75, 85, and 98.4% in the management of proximal, midureteral, and distal ureteral stones, respectively. Our overall success rate was 89.9 percent. In a study by Hong the corresponding rates were found to be 80.3, 93.8, 96.9, and 93.5%, respectively. Manohar detected a success rate of 84% for PL in the treatment of ureteral stones. Yücel et al. reported a success rate of 84.3% for PL applied for the ureteroscopic treatment of stone disease in pediatric cases. Khaladkar indicated a success rate of 79.2% in midureteral stones larger than 1.5 cm in diameter. Keshvari and Abdel-Kader reported a 100% success rate for PL in the endoscopic treatment of ureteral stones in pregnant women. However these studies were performed with limited number of patients. Our success rates were similar to those reported by Monomar et al., Khaladkar et al., Hong et al., and Yücel et al. Still they are approaching to those indicated by EAU. Based on our study, and those cited in the literature, PL is an effective modality.

European Association of Urology indicates LL as a gold standard modality in that it can be used both in rigid, and flexible ureteroscopy with its effectiveness against all stone types. Manohar et al. reported the success rate of laser lithotripsy as 84 percent. Kassem indicated success rate of laser lithotripsy as 12.9%, in the management of ureteral stones longer than 12.9 mm. However, Salvado et al. expressed the success rate of laser lithotripsy in the management of distal ureteral stone as 96 percent. According to Cimino et al. overall success rate of laser lithotriptors in the management of all ureteral stones is 86.1 percent. In our study, stone-free rates we achieved with LL were 74.2, 96, and 92.2% in the management of proximal, midureteral, and distal ureteral stones, respectively. Our overall success rate was 87.9% which was in accordance with the literature.

In their study, Knispel and Hong indicated lower success rates for proximal ureteral stones when compared with the stones in the midureteral, and distal ureteral stones. Besides, Hong indicated significantly lower success rates in the treatment of the proximal ureteral stone relative to distally located stones. According to Cimino midureteral, and distal ureteral stones have a higher stone-free rates. In our study, anatomic location of the stone affected our success rates. In both groups, our success rates in proximal ureter were significantly lower than those we achieved with distal ureteral stones. Our outcomes also support those of the other studies.

The most important disadvantage of pneumatic lithotriptor (PL) is migration of the stone into renal collecting system. Razzaghi et al. detected incidence of stone migration into renal collecting system as 17.9% in the PL group but, without such a complication (0%) in the laser group. Salvado et al. compared
PL, and LL groups as for stone migration without any difference between groups. Manohar et al.\cite{3} reported stone migration rates as 24, and 16% for LL, and PL groups, respectively, without any statistically significant difference between groups. Thanks to sophisticated technology, improvements in the design of ureteroscopes, and also auxiliary instruments have been achieved. Use of catheters preventing stone migration has increased success rates considerably. Eisner et al.\cite{37} used catheters which prevented stone migration, and reported a success rate of 100% in their LL series. Bastawisy et al.\cite{38} used the same type of catheters in PL, and they also indicated 100% success rates. In our study, stone migration was observed in 10 (9.1%) URS-PL, and 7 (6.5%) URS-LL patients. Despite somewhat higher stone migration rates in the PL group, the abovementioned rates are not statistically significant. EAU, recommends use of stone basket, and catheters to prevent stone migration.\cite{1} Even though stone migration is an unwanted adverse event, it can be seen in both techniques, and with advanced technology, its rates are decreasing. In our study, our stone migration rates in both techniques are within acceptable limits.

The complication rate of ureteroscopy ranges between 9, and 25 percent. However the incidence of major complications as ureteral avulsion or stricture is lower than 0.1 percent.\cite{1} Previous perforation is the most important risk factor for complications.\cite{1}

In our study, we haven’t encountered major complications as ureteral avulsion, sepsis, urinoma or hematuria requiring treatment. Therefore it is not possible to comment on comparative complication rates of both methods. Minor complications observed did not require treatment.

When two methods are compared, PL is easily installed, and has a lower cost when compared with LL.\cite{5} Öztürk et al.\cite{8} performed a survey study on 106 urology residents, and urologists in Istanbul, and detected that PL was available in the clinics of all participating patients, while only 61% of these clinics had laser lithotriptors. Easy installation, and lower cost are most important advantages of PL. Lack of any significant difference between outcomes of these two methods, but very high costs of LL, made us to wonder whether LL is a real necessity or it is an imposition of the medical industry. In the endoscopic management of ureteral stones, as an intracorporeal lithotripter, pneumatic lithotripter is as effective as laser lithotripter, and it can be used safely. Operative times, surgical success rates, and catheter removal times do not differ between these two methods, however length of hospital stay is significantly shorter in favour of laser lithotripter. Even though due to its advanced technology, and easy availability LL has become popularized, currently with similar efficacy, and complication rates, and higher cost-effectiveness, PL is a preferred alternative lithotripsy method in the endoscopic treatment of ureteral stones.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the ethics committee of Samsun Training and Research Hospital (14.09.2012/2837).

**Informed Consent:** Written informed consent was obtained from patients who participated in this study.

**Peer-review:** Externally peer-reviewed.


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