Influence of stone location on rate of stone clearance and complication for holmium laser lithotripsy

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Abstract

Background: Ureteroscopy (URS) is a precise, minimally invasive surgical intervention that can assess the entire collecting system to treat a stone using intracorporeal lithotripsy. The implication of laser technology in the development of lithotripter fibres has revolutionized intracorporeal lithotripsy.

Objectives: The impact and the outcome of holmium: YAG laser ureterolithotripsy in treating proximal and distal ureteric stones were investigated.

Methods: A total of 100 patients harboring proximal (n=64) and distal (n=36) ureteral stones underwent semirigid Ho ureterolithotripsy. The degree of hydronephrosis, stone size, location, impaction, and complication and stone-free rates were recorded.

Results: The mean stone size for proximal and distal stones was 7.1 ± 3.6 mm and 6.2 ± 2.5 mm, respectively. The stone-free rates on the first postoperative day were 77.5% (29/36) for proximal and 95.3% (62/64) for distal stones (p < 0.0001). For proximal stones ≤10 mm and ≥10 mm, the stone-free rate was 80.5% (22/28) and 74.3% (6/8) (p=0.4), and for distal stones, it was 97.3% (58/60) and 94.3% (4/6) (p=0.2). Stone-free rates for radio-opaque versus radiolucent stones in proximal stones were 79.6% (23/30) versus 77.9% (4/6) (p=0.8), and 97.6% (58/64) versus 96.2% (8/64) in distal stones (p=0.5). Impaction correlated significantly with stone-free rates (p < 0.0001). Stone-free rates for non-impacted versus impacted proximal stones were 83.3% (20/24) versus 66.6% (8/11) (p=0.003), and for distal stones, they were 97.6% (44/45) versus 89.4% (17/19) (p<0.003), respectively. The presence or degree of hydronephrosis did not correlate with treatment success (p=0.4, p=0.8). The presence of intraoperative complications correlated significantly with proximal compared to distal ureteral stone location (p=0.004). Auxiliary measures in proximal versus distal stones were performed in 19.3% (6/31) versus 3.2% (2/64) (p<0.001).

Keywords: Holmium laser, ureterolithotripsy, stone clearance, proximal stones, distal stones

Introduction

During the early 1980s, the treatment of stones in urinary passageways, namely ureteral calculi, was significantly improved by the introduction of extracorporeal shockwave lithotripsy (ESWL) [1, 2]. Initially, endoscopic ureterolithotripsy seemed to have been overshadowed by another approach. However, as time passed, both treatments gained recognition and were given equal importance. Role in the management of ureteral calculi [3]. Endoscopic treatments for stone fragmentation use many energy sources including electrohydraulic, ultrasonographic, pneumatic, and laser technologies. These laser technologies include ruby, carbon dioxide, neodymium: yttrium-aluminium-garnet (Nd:YAG), dye, alexandrite, and holmium: yttrium-aluminium-garnet (Ho: YAG) lasers [4]. Ureteroscopy plays a crucial role in treating ureteric calculi, thanks to technological improvements that make it simpler to reach stones in different areas of the kidney and ureter. Specifically, advancements in ureteroscopic equipment highlight the need for suitable and efficient downsized intracorporeal lithotripsy devices [5, 6]. The term "laser" stands for "light amplification by stimulated emission of radiation." The Holmium: Yttrium, Aluminum, Garnet laser, often known as the holmium: YAG laser, was created in the early 1990s [7]. In 1968, Mulvaney and Beck [8] created a ruby laser that could break down calculus using a significant amount of energy, which led to the generation of excessive heat. The practical application of the device was prevented due to the heat impact on the surrounding tissues.
Subsequent efforts were made to use continuous wave carbon dioxide and Neodymium: YAG (Nd: YAG) lasers. The limitations of carbon dioxide laser transmission via non-toxic fibers suited for endoscopic use, as well as the heat effects on nearby soft tissues associated with Nd: YAG devices, are significant. Their clinical utility [9] after the initial experience with these lasers, it became clear that successful laser lithotripsy requires certain conditions. These include the ability to transmit energy through optical fibers, the need to minimize thermal effects at a distance, and the generation of a shock wave strong enough to surpass the tensile strength of the stone [10]. The first laser lithotrite that achieved commercial success was the coumarin pulse dye laser. However, it was unable to effectively break down cystine stones. The pulsed dye laser has shown safety and efficacy in clinical applications, as seen in studies with Nd: YAG and Alexandrite lasers [11, 12]. The Ho: YAG laser is the most recent technology that operates at a new wavelength for medical purposes related to the urinary system the research and development of lithotripsy using the Ho: YAG laser began in 1990, and its clinical use was initiated in 1993. This versatile laser integrates the characteristics of carbon dioxide and Nd: YAG laser to provide a single device that can perform tissue cutting and coagulation. Due to its ability to be transmitted across optical fibers, the holmium wavelength is particularly well-suited for this purpose. For intracorporeal/endoscopic lithotripsy The Ho: YAG laser is a pulsed laser that generates light at a wavelength of 2100nm. It is a solid-state laser. The laser utilizes the rare earth metal holmium as its active medium. It may be paired with either a yttrium-aluminium-garnet (YAG) crystal to form a Ho: YAG laser or with a yttrium-scandium-gallium-garnet (Ho: YSGG) crystal. The different forms of energy may trigger the fragmentation of most urinary calculi. On the other hand, the precise process by which stone fragmentation occurs with the holmium laser remains unknown. The research indicates that it primarily arises from a thermal effect, with a secondary impact of shockwave or cavitation action. Zhong et al. [14] conducted a study using high-speed photography and acoustic pressure measurements to examine the fragmentation of stones using pulse-dye and holmium laser. Compared to the spherical cavitation, bubble, and strong shockwave emission generated by the pulse-dye laser, the holmium laser with a longer pulse length creates a stretched-out bubble with a much less powerful shockwave emission [15]. Thus, it seems that stone fragmentation is primarily influenced by a thermal action that leads to the process of "stone vaporization". It is possible that each laser pulse causes heating on the stone surface, leading to the erosion of a tiny portion of the stone. When stress fractures occur in the stone, the emission of relatively mild shockwaves may also help break up the stone along these weaker cleavage planes, contributing to the fragmentation process. Several researchers have observed that holmium laser lithotripsy operates by means of a drilling mechanism, in which tiny fragments of stone are vaporized, resulting in the release of a fine dust composed of stone particles [16, 17, 18]. Essentially, the main impact of the holmium laser in urological applications is mostly attributed to its thermal effects, which arise from its high absorption rate. A liquid substance composed of hydrogen and oxygen molecules, typically transparent, odorless, and tasteless, that is essential for the survival of all living organisms.

**Patients and Methods**

From January 2021 to October 2022, a total of 100 patients with ureteral stones, namely 36% (n=36) with proximal stones and 64% with distal stones, received Ho: YAG ureterolithotripsy at the MOSUL MEDICAL CENTRE. The prospectively collected patient data comprised demographic information, primary symptoms (Such as loin pain, renal colic, haematuria, and fever), laboratory tests such as urinalysis, urine culture, serum creatinine measurement, and a coagulation profile. Urinary cultures yielded positive results in 5 people (5%), who were given suitable antibacterial medications prior to undergoing ureterolithotripsy. Stones can be detected either through K.U.B and ultrasound when symptoms are present, or through intravenous urography during the period of no symptoms. The detection also takes into account factors such as the size and location of the stone (Whether it is near or far from the pelvic brim), the presence and severity of hydronephrosis, the blockage caused by ureteral stones, the success rate of removing the stones, and any associated complications. Before performing Ho: YAG ureterolithotripsy, 10 patients had failed extracorporeal shock wave lithotripsy (ESWL) treatment for their ureteral stones. Hydronephrosis was identified by ultrasonography before doing ureterolithotripsy. The patients were categorized into four groups based on the severity of stone-induced hydronephrosis. Group 0 had no dilation of the urinary system. Group 1 had mild dilation of only the renal pelvis. Group 2 had dilation of both the renal pelvis and calices. Group 3 had additional rarefaction of the renal parenchyma. Impacted ureteral stones were specifically identified as those that were firmly attached to the wall of the ureter, as confirmed during endoscopic examination [21]. The procedure of Ho-YAG ureterolithotripsy was performed on an inpatient basis with the use of general anesthesia. Assuming the lithotomy posture. The stone treatment was conducted by the urologist and overseen by resident physicians. Antibiotics were given as a preventive measure throughout the whole procedure of placing the stent, and 89-Fr semirigid ureteroscopes from KARL STORZ Germany were consistently used. A semi-rigid ureteroscope was inserted into the ureter, equipped with a safety wire, to address both proximal and distal ureteral stones. Lithotripsy was performed using 600-mm laser fibres and a 50W AURIGA XL laser generator from Germany. The energy and frequency parameters should be adjusted within the range of 0.6 to 1.8 J and 5 to 10 Hz, respectively. The termination conditions for laser lithotripsy included either the total removal of fragments or the presence of residual pieces measuring 2mm or less, together with the anticipation of natural passage. For the purpose of assessing the effectiveness of the therapy, a radiograph of the kidney ureter-bladder (KUB) and renal ultrasonography were conducted on the day after the surgery. When dealing with uncertain cases with radiolucent stones, a non-contrast computed tomography or intravenous may be used. A urography procedure was conducted. Treatment success was defined as the absence of stones or the presence of radiolucent stones in equivocal instances, as determined by noncontrast computed tomography or intravenous imaging. A urography procedure was conducted. Treatment success
was defined as the absence of stones or the presence of pieces measuring 3 mm or less on KUB and renal sonography performed the day after Ho: YAG ureterolithotripsy. Follow-up (3-6 months) was conducted to identify any adverse effects. The analysis was conducted using IBM SPSS STATISTICS version 20. Students previously compared the age, duration of surgery, and size of stones comparing patients with stones located either proximally or distally. Chi-square tests were used to compare gender, hydronephrosis, and impaction. The threshold for statistical significance was established at a p-value of less than 0.05.

**Result**

Mean age was 48.2 + 15 yr, and 27 female and 73 male patients were treated. See table 1 and fig. (1).

### Table 1: Characteristics of patients with proximal versus distal ureteric stone

<table>
<thead>
<tr>
<th></th>
<th>Proximal</th>
<th>Distal</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Yrs)</td>
<td>50.7±14</td>
<td>46.9±15</td>
<td>0.004*</td>
</tr>
<tr>
<td>Stone *size mm</td>
<td>7.1±3.6</td>
<td>6.9±2.5</td>
<td>0.0006*</td>
</tr>
<tr>
<td>Operation Time (min)</td>
<td>38.9±22.4</td>
<td>36.1±19.4</td>
<td>0.2*</td>
</tr>
<tr>
<td>m/f (%)</td>
<td>72.2/27.8</td>
<td>73.4/29.6</td>
<td>0.7*</td>
</tr>
<tr>
<td>Hydroneph (%)</td>
<td>80.5</td>
<td>81.25</td>
<td>0.9</td>
</tr>
<tr>
<td>Impaction (%)</td>
<td>33.3</td>
<td>29.6</td>
<td>0.3</td>
</tr>
</tbody>
</table>

**Dimensions of the stone**

The average size of stones located in the proximal region was 7.1 ± 3.6 mm, whereas for stones located in the distal region it was 6.2 ± 2.5 mm (as shown in Table 2). There was a significant correlation between the size of the stone and the overall success rates (p = 0.038).

When categorized by location, the stone-free rate for proximal ureteral stones was 85.5% and 74.3% (p=0.4) for 10 mm and 2 10 mm, respectively. In comparison, the stone-free rate for distal stones was 97.3% and 94.3% (p=0.1). These results are shown in table 3.

### Table 2: Characteristic of stone clearance in 1st post-operative day

<table>
<thead>
<tr>
<th></th>
<th>Proximal</th>
<th>P value</th>
<th>Distal</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone Clearance</td>
<td>77.7%(28/36)</td>
<td></td>
<td>96.8%(62/64)</td>
<td></td>
</tr>
<tr>
<td>Stone size&lt;10'10 m</td>
<td>80%(22/28)/74.3(6/8)</td>
<td>0.4</td>
<td>97.5%(28/60)/94.3(4/6)</td>
<td>0.2</td>
</tr>
<tr>
<td>Radiopaque/radioleucent</td>
<td>79.6%(23/30)/77.9(4/6)</td>
<td>0.8</td>
<td>97.6%(58/64)/96.2(8/64)</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Table 3: Stone size and treatment outcome of nonimpact versus impacted ureteral stones

<table>
<thead>
<tr>
<th>Ureteral stones (n=100)</th>
<th>Non impacted(n=69)</th>
<th>Impacted(n=31)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal+distal &lt;10 mm≥10 mm</td>
<td>69% 85.5/(59/69) 14.5%(10/69)</td>
<td>31% 87.1/(27/31) 12.9% (4/31)</td>
<td>0.9</td>
</tr>
<tr>
<td>Hydronephrosis absent/present</td>
<td>20.28/79.72</td>
<td>16.13/83.87</td>
<td>0.2</td>
</tr>
<tr>
<td>Operation time</td>
<td>36.4 20.2min</td>
<td>38.6+21.1min</td>
<td>0.3</td>
</tr>
<tr>
<td>Stone free (Overall)</td>
<td>94.2%</td>
<td>80.6%</td>
<td>0.0001</td>
</tr>
<tr>
<td>Stone free (Proximal Stones)</td>
<td>83.3%</td>
<td>66.6%</td>
<td>0.003</td>
</tr>
<tr>
<td>Stone free (Distal Stones)</td>
<td>97.7%</td>
<td>89.4%</td>
<td>0.0003</td>
</tr>
<tr>
<td>Intraoperative complication</td>
<td>1.4%</td>
<td>6.4%</td>
<td>0.02¹</td>
</tr>
<tr>
<td>Post-operative complication</td>
<td>1.3%</td>
<td>9.6%</td>
<td>0.005i</td>
</tr>
<tr>
<td>Auxiliary measures</td>
<td>5.79%</td>
<td>16.12%</td>
<td>0.0001&gt;i</td>
</tr>
</tbody>
</table>

* T test I chi square

Impaction

Impaction was seen in 31% (n=31) and showed a strong correlation with success rates in both proximal and distal stones (p<0.0001). The percentage of stone-free status in proximal stones was 66.6% for impacted stones compared to 83.3% for nonimpacted stones. In distal stones, the stone-free rate was 89.4% against 97.7% (p=0.003) (p<0.0003). The table is labeled as “3.fiq 2.”

Fig 2: Percentage of stone clearance in regard to site of stone and impaction

An important association was seen between impaction and both intraoperative (p = 0.02) and postoperative complication rates (p = 0.005). However, no significant connection was identified between impaction and the presence (p = 0.2) or the severity of hydronephrosis (p = 0.3). Or the size of the stone (p=0.9, Table 3).

Hydronephrosis

Prior to ureterolithotripsy, hydronephrosis was demonstrated in 80.5% of proximal versus 81.2% of distal ureteral stones (p=0.9). The degree of a hydronephrosis was equally distributed within both groups (p= 0.4) and correlated positively with stone size (p<0.0001). A total of 18.2% of patients had no urinary system dilatation (group 0), 27.9% had a dilatation of the renal pelvis only (Group 1) Hydronephrosis had a dilatation of the renal pelvis 53.2% and calices (Group 2), and 0.7% had an the renal parenchyma (Group 3). The presence or degree of hydronephrosis detected by ultrasonography did not affect stone-free rates (p = 0.4, p = 0.8) or intraoperative (p = 0.8, p=0.6) and, postoperative complication rates (p = 0.1 and 0.3).

Complications

All patients exhibiting symptoms of urosepsis were treated with D.J insertion before to undergoing laser ureterolithotripsy. The stone size was notably greater in these cases. The data has a mean of 10.4_6.1 mm with a significance level of p = 0.02. A total of 7% of patients, namely 7 individuals, were impacted. Due to problems, A higher incidence of problems was seen in the proximal ureter (8%) compared to the distal ureter (4%), and in cases with impacted stones (10%) compared to nonimpacted stones (3%). The incidence of complications was considerably greater in cases with proximal stones (p = 0.04) and impacted stones (p = 0.001). However, there was no correlation between the complication rate and factors such as age, gender, hydronephrosis, or stone size. The p-value is greater than 0.05. During the surgery, some difficulties occurred, such as bleeding or a leak in the ureter, which resulted in the need to temporarily stop the URS treatment for one patient. This required further procedures to be performed. Two cases (n=2) of ureteral perforations associated to intraoperative laser procedures were observed, accounting for 2% of the total cases. Both individuals had hydronephrosis, with one experiencing impacted proximal ureteral stones and the other having a ureteral stricture that required laser incision to reach the stones. Thankfully, the perforation healed well while a ureteral stent was in place for 1-4 weeks, and there was no occurrence of restenosis. The follow-up period for these patients lasted 6-8 months. The occurrence of postoperative problems was equally divided between the proximal and distal ureter, affecting 3% (n = 3) of patients. Stent dislocation was excluded from this count, since it only happened in one extra patient with hydronephrosis. The value of n is 3. 3 percent one patient had ureteral stenosis that required the extended implantation of a stent. The symptoms appeared four months after...
undergoing ureterolithotripsy for a distal ureteral stone with significant hydronephrosis. The 6-month postoperative I.V.U revealed no abnormalities. Severe complications requiring ureterouretrostomy with the attempted removal of the proximal ureteric stone. Subsequent investigation shows no evidence of any narrowing or constriction. Adjacent to the anastomosis

Retreatment
Two patients had unintended displacement of a stone into the kidney during a Ho: YAG procedure. In the same session, a DJ was placed and successfully underwent ESWL one month later. Four patients required retreatment, with two displaced pieces in the kidney and two in the ureter. The retreatment was successful in all cases, with a 100% success rate. One patient, who was scheduled for retreatment after primary ureteroscopy (URS), had spontaneous stone passage after one month. 65% of patients need the insertion of a DJ for various reasons, such as complicated stones, a significant stone load, mucosal laceration, and ureteric perforation. 80% of patients were released within a period of 2 days. Some individuals allocate a greater amount of time, ranging from 3 to 50 days. In the event of ureteric perforation, urosepsis, or prolonged postoperative hematuria.

Discussion
Previous study has shown that the size of a stone does not have an influence on the pace at which it is cleared in ureteral stones. Additionally, ureterolithotripsy is suitable for stones that are between 16 mm and greater than 20 mm in affected upper ureteral stones, as supported by references [23] and [24]. These findings align with our study, which demonstrated favorable outcomes for proximal ureteral stones measuring up to 22 mm and distal ureteral stones measuring up to 17 mm. Out of the patients with stones larger than 10 mm, only three required further surgeries, while the other 24 patients (88.9%) were free of stones. The rates of complications did not show a significant correlation with the size of the stone, but were greater in cases where the stone was affected (Table 3). Impacted stones are stones that have remained unaltered in the ureter for more than 2 months [25], or stones that cannot be passed by a wire or ureteral catheter [21], those presenting with ureteral stones measuring less than 5 mm and experiencing recurring colic pain, as well as those with ureteral stones measuring 5 mm or larger, were both treated within a two-week timeframe. Thus, impaction was precisely determined using endoscopy by seeing its adhesion to the ureteral wall, requiring the use of the Ho: YAG to dislodge it. Patients with impacted ureteral stones may have inflammation of the ureteral wall, along with swelling, scarring, and thickening of the urothelial lining in the area where the stone is located [26]. Inflammatory responses to the stone material and ischemia caused by stone-induced ureteral wall pressure, which stimulates fibrosis and ureteral edema, might hinder stone removal and increase the risk of injury to the ureteral wall [21, 27]. The disintegration of impacted ureteral stones has been significantly enhanced with the use of the Ho: YAG laser, and positive outcomes have also been seen in cases of non-impacted ureteral stones. The incidence of laser-related problems in impacted ureteral stones was 2.3%, while it was 0.2% in non-impacted stones. Intra- or perioperative radiography identified instances of ureteral perforation.

Perforations were seen after the treatment of proximal and distal ureteral stones measuring 10 mm. Six patients exhibited stone impaction. All patients who had ureteral perforations had successful recovery after the insertion of a stent in the affected area for a duration of up to 4 weeks. In order to prevent ureteral perforations, it is crucial to consistently visually recognize the laser tip and its tracer light while disintegrating, particularly when anatomical challenges hinder access to the stone. To prevent ureteral perforation, it is recommended to maintain a gap of more than 1 mm between the laser tip and the ureteral mucosa [29]. However, the likelihood of perforating the ureter and the resulting stricture rate are significantly reduced when the reported depth of heat damage is modest. The range of values is between 0.5 and 1 mm, namely, 20, 30, and 31. Research has provided evidence of the safety of the Ho: YAG in comparison to electrohydraulic lithotripsy [32-34]. This series provided evidence of the Ho: YAG's high level of safety, with just a 1% occurrence of laser-related complications and a 1% occurrence of strictures that required ureteral reimplantation. This aligns with a complication rate of less than 1% and a stricture rate of 0.35% as documented by Sofer et al. [23]. Furthermore, research has shown the effectiveness and safety of the Ho: YAG in those who may be at higher risk, such as pediatric patients, pregnant women with urolithiasis, or patients with coagulopathy [35-38]. Effective fragmentation was also accomplished when conducted as a subsequent treatment after unsuccessful ESWL. Singal et al. [39] documented a mean success rate of 90% after secondary ureterolithotripsy, which aligns with our own success rate of 88.9% (n = 36). Our study found that the lack of impaction led to a stone-free rate of 94.6%, whereas affected systems had a stone-free rate of 82%. Comparable findings have been seen in extracorporeal shock wave lithotripsy (ESWL) procedures for stones located at the beginning of the ureter. The increased speed at which stones are cleared following fast extracorporeal shock wave lithotripsy (ESWL) may be attributed to the reduced severity of ureteral edema and fibrosis during the first stage of stone impaction [40-42]. Based on that premise, the fast extracorporeal shock wave lithotripsy (ESWL) may be attributed to the reduced severity of ureteral edema and fibrosis during the first stage of stone impaction [40-42]. Based on that premise, the fast extracorporeal shock wave lithotripsy (ESWL) has garnered significant interest. Among those experiencing little stone dislocation the use of flexible ureteroscopic access provides a secure and effective method of therapy [43]. However, at our institution, the issue of displaced substantial pieces into the lower pole may be resolved by using DJ with ESWL, since flexible ureteroscopic is not accessible.

Conclusion
Our work demonstrates that Ho: YAG lithotripsy is a very secure treatment that effectively disintegrates ureteral stones, regardless of their size, hardness, or the presence of simultaneous hydronephrosis. The success of ureterolithotripsy in this series was mostly determined by the stone's placement in either the proximal or distal part of the ureter, as well as its impaction in the ureteral mucosa, which might hinder the total removal of the stone. Ureterolithotripsy performed on proximal ureteral stones exhibited notably elevated rates of intraoperative complications and retreatments as compared to distal stones. There was no correlation between the hardness and/or opacity of the stone and the total stone-free rates.
References


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