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Urinary Tract Lithotripsy Using Holmium: YAG (2100nm) Laser

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Abstract: Background: Laser urinary stone lithotripsy is an established endourological modality. Ho:YAG(2100nm) laser have broadened the indications for ureteroscopic stone managements to include larger stone sizes throughout the whole urinary tract. Purpose: To evaluate the effectiveness and safety of Holmium: YAG(2100nm) laser lithotripsy with a semirigid uretero scope for urinary stone calculi in a prospective cohort of 17 patients. Patients and Methods: Holmium: YAG(2100nm) laser lithotripsy was performed with a semirigid ureteroscope in 17 patients from September 2016 to December 2016. Calculi were located in the lower ureter in 9 patients (52.9%), the midureter in 5 (29.4%), and the upper ureter in 3 (17.64%).The parameters used were, average Power(20W),Energy(1.5-2J),Pulse duration(75-100ms),Frequency(10Hz) and Spot size(0.55mm). Results: The overall stone-free rate was (100%), this rate being for calculi in the lower ureter ,midureter and for calculi in the upper ureter. Complications occurred in 2 patients (11.76%).The mean operative time(34.9minutes). Conclusions: Ho:YAG laser lithotripsy is standard in treating ureteric calculi located in the upper, mid and lower ureter. It is able to fragment ureteric stones of all known composition and has an excellent safety profile.

Keywords: Holmium: YAG laser, Laser lithotripsy.

Introduction

Lithotripsy of urinary calculi is often based on ultrasound techniques. However, not all calculi are equally indicated for such an external therapy. In particular, those calculi which are stuck inside the ureter are in an extremely inconvenient location. In these cases, laser-induced lithotripsy offers the advantage of directly applying energy to the vicinity of the calculus by mean of a flexible fiber [Markolf H Niemz,et.al,2007]. The treatment of urinary stones throughout the whole urinary tract via an endoscopic approach has gained widespread acceptance due to technical advancements in endoscope and lithotripter techniques .The pulsed holmium:YAG (Ho:YAG) laser has become the preferred lithotripter device. One major advantage of this energy source is that laser energy can be delivered through flexible optical fibers that can be advanced through flexible and rigid endoscopes. The Ho: YAG-laser is capable of fragmenting stones of any composition and hardness; consequently a high stone free rate is achievable. A subject of the highest importance in Ho:YAG-laser research is the reduction of the mean stone fragment size in order to improve the discharge of fragments from the urinary tract and to increase treatment success. This process is called ‘stone dusting’ [Markus J. Bader, et.al, 2015].

Currently, the term ‘stone dusting’ stands for laser settings with low energy per pulse and a high pulse repetition rate. Today, this treatment approach is mainly the domain of multi-cavity high-power Ho: YAG laser systems which are able to operate at pulse frequencies of more than 40 Hz.[Markus J. Bader, et.al,2015].

The Ho: YAG laser is a solid state, pulsed laser that emits light at 2100nm. The laser active medium is the rare earth element holmium and it can be combined either with a yttrium-aluminum-garnet (YAG) crystal as Ho: YAG laser or with yttrium-scandium-gallium-garnet (Ho:YSGG). Light at the 2100 nm wavelength is invisible to the human eye and falls in the mid -infrared region of the electromagnetic spectrum. The optical absorption coefficient for water at this wavelength is approximately 40 cm-1, so that the holmium wavelength is absorbed significantly by water. Since human tissues are composed mainly of water, the majority of the holmium energy is absorbed superficially and this results in superficial cutting or ablating only [Lt Col AS Sandhu, et.al, 2007].

In addition to its tissue ablating properties, the holmium laser has also been shown to have excellent stone ablating effects [Lt Col AS Sandhu, et.al, 2007]. The laser energy is delivered down fibers which vary in diameter from 200 to 360μm. The zone of thermal injury is limited from 0.5 to 1mm from the laser tip. No stone can withstand the heat generated by the Ho:YAG laser [John Reynard,et. el,2013].

In summary the majority of the holmium laser effect during urological applications are due to its thermal effects as a result of its strong absorption by water. This results in excellent superficial tissue ablation and a significant haemostatic effect because of the residual thermal injury associated with the laser energy. A significant advantage of the weak pressure wave as compared to the other lasers is less retropulsion of stone fragments. [Lee H, Teichman JM, et.al, 2003].

Aim of Study:

To study the efficacy and safety of Ho:YAG laser(2100nm) in the treatment of urinary stone.

Patients, Materials and Methods

Procedure for performing laser lithotripsy:

The entire procedure was always performed under direct vision with the laser fiber in contact with the stone. If stone dust obscures vision (“snow storm” effect), halt lithotripsy until irrigate clears field of view, and used with caution when drilling through the stone to avoid inadvertent injury to the ureter. Direct laser energy contact should be avoided with a guide wire or stone basket as the latter may break, and extend laser fiber 2-3 mm beyond endoscope tip to avoid damage to the lens or working channel. One of the challenges when treating stones in the ureter is preventing retropulsion of the stone fragments. If a semi rigid ureteroscope is being used, the fragments may become inaccessible if they are pushed up to the kidney. The surgeon may then have to switch to flexible ureteroscopy to gain access to the renal collecting system, this increases operating time and incurs additional cost. If retropulsion of some of the fragments occurs unknowingly, it may lead to reduced stone-free rates, increased stone-related events, and potentially even the need for additional procedures. We attempt to prevent retropulsion by pinning the stone between the laser fiber and ureteral mucosa prior to activating the laser. Retropulsion can also be avoided by minimizing strong jets of irrigation and using a smoother, consistent flow to allow clear visualization of the stone.

Patients and Methods:

Between September 2016 and December 2016, a prospective cohort of 17 consecutive patients with ureteral calculi were evaluated, including 14 men and 3 women, 23to 60years old .Informed history was taken (Medical, Surgical and drug history).Five patients had surgical history of DJ stenting for obstructing ureteric stone. Investigations done, as urine analysis and blood investigations to exclude anemia. Renal function assessment and bleeding tendency, KUB,IVU and Ultra sonogram were done preoperatively, seven patients were having hydro nephrosis and hydro ureter. All patients were treated by retrograde ureteroscopy with a

Stors8F semi rigid ureteroscope and a Holmium: YAG laser after informed consent was obtained. The Ureteroscopic procedure was performed by staff of urology in the hospital of Al Sadder Medical City (Najaf). There were multiple and solitary stones in 5 and 12 patients, respectively (multiplicity was ureteric stone with unilateral and bilateral renal stones). The calculi were in the lower ureter in 9 patients (52.9%), the mid ureter in 5/17 (29.4%), and the upper ureter in 3/17(17.64%). The mean stone size was 13.8 mm (range 7–25mm), as measured on preoperative intravenous urograms (IVUs) and ultra-sonograms and recorded as the maximum diameter. 5/17 of the patients (29, 4%) had a history of failure of ESWL.

Ureteroscopic procedures were performed on an inpatient basis using a Stors8F semi rigid ureteroscope with the patient under spinal anesthesia. Patients were placed in the standard lithotomy position and sterilization of the area. The ureteroscope was passed into the bladder through the urethra under visual monitoring, and a 0.035- inch guidewire was inserted into the ureteral orifice to facilitate passage of the ureteroscope. Balloon dilation was not performed. Continuous low-pressure fluid flow was necessary to maintain visibility. Ureteric manipulations were aiming to direct laser impulses to the middle of stones and their fragments under monitor vision to allow fragmentation without ureteric injuries.

Laser lithotripsy was delivered using a pulsed 30 W Holmium laser (Litho Holmium Yag Laser 30W,Italy). A 550 micrometer fiber was used in all patients. Laser energy generally was applied at an initial setting of 1.5 J/pulse at a pulse rate of 10 Hz and increased incrementally by 0.2 J/pulse as necessary. The maximum power was 20 W. Stones were fragmented to a particle size of 0.2 -0.3 cm.

Basket stone removal was considered for fragments >2 mm in size after laser fragmentation to achieve samples for stone composition analysis.

Bad visibility was mainly due to macro hematuria as well as stone dust leading to turbidity of fluid media and obscuring vision. Postoperative urethral catheterization (Folly s) were mandatory for all patients with variable sizes, then the patients transferred to the recovery room, then to the ward, and giving medical treatment as intravenous fluid, analgesia and antibiotics.

Results:

All patients (17/17; 100%) were stone free after a single Ureteroscopic procedure. The stone-free rate stratified by stone location was 100% in the Lower, Mid and Upper ureter (Table 1), (Fig:1).

The intraoperative complication rate was 11.76%, in tow patients including ureteral partial mucosal injury by the ureteroscope in one, and mild bleeding in the other. Minimal injury was managed by ureteral stenting.

The mean operative time was 34.9 minutes (range 12–67 minutes), for upper ureteric stone was (37.5 min), for mid ureteric stone was (38 min), and the shortest time was for lower ureteric stone (31min).

The mean ureteric stone size was (13.8mm), the upper ureteric stone was(15mm),mid ureteric stone was(13.2mm),and the lower ureteric stone was(13.7mm).

The setting of pulse energy was ranged 1.5 - 2 J/pulse at a frequency of 10 Hz. All patients were hospitalized for 24 to 48 hours for medical observation and giving intravenous fluid, antibiotics and analgesia.

Table (1): Stone-free rate stratified by stone location**:**

Site	**No. of patients having laser lithotripsy**	**Mean stone size (range) (mm)**	**Percent (no.)of stone free**
Lower ureter	**9**	**13.7 (7–25)**	100 %(9)
Mid ureter	**5**	**13.2 (7–22)**	100 %(5)
Upper ureter	3	15 (11–19)	100%(3)

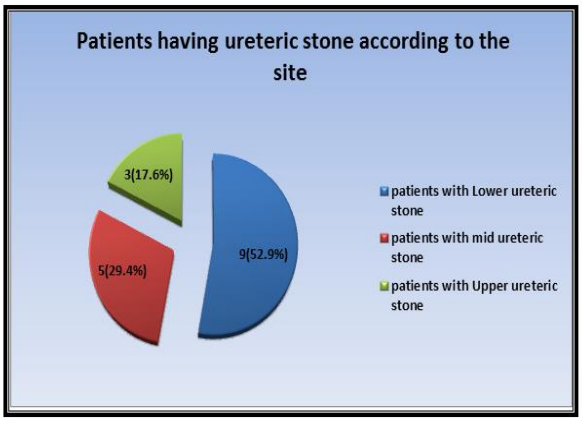

Fig. (1): number and percentage of patients having ureteric stone according to the site.

Discussion

The current study included cohort of patients with ureteral calculi requiring lithotripsy for stone retrieval. Success in the treatment of ureteral stones by laser is reported in 91% to 100% of cases, with a mean stone-free rate of 95 % [Lingeman JE, et.al, 2002] and 92% [Haowen Jiang,et.al,2007]. In the current study, the mean stone-free rate was 100% with a single Ureteroscopic procedure. The high success stone-free rate for calculi in the upper, mid and lower ureters in the current series after a single procedure (100%). The current mean operative time (34.9 minutes) was shorter for lower ureteral calculi than for mid and upper calculi. This could be explained with the larger stone burdens and the effort to completely "melt down" the calculi with laser and the effort to remove as much stone debris as possible leaving no significant fragments. Other cause due to ease to reach the distal ureter stone and dealing with it .And this is shorter than the operative time of other study [Wael Y Khoder,et.al,2014].

Clear vision to ease direct access to the targeted stones is essential during Ureteroscopic laser lithotripsy to avoid perforation. Decreased visibility leads to prolonged operative time and increase the potential risk of injuring the ureter [Wael Y Khoder, et.al, 2014].

The clear indications for stenting include ureteral injury/stricture, solitary kidney, renal insufficiency or large residual stone burden [Lee H, Teichman JM, et.al, 2003]. Generally, routine postoperative ureteral stenting after Ureteroscopic laser lithotripsy is still a subject of debate. On one hand, stent-related morbidities like bladder irritation and mild back discomfort during urination were demonstrated to constrain postoperative quality of life. On the other hand, ureteral stenting was thought to prevent postoperative urinary sepsis by avoiding sudden ureteral obstruction by calculus fragments, blood clots or ureteral mucosal edema[Haowen Jiang,et.al,2007, Wael Y Khoder,et.al,2014]. Furthermore several prospective randomized controlled trails comparing a non-stented versus stented Ureteroscopic lithotripsy reported the same result [Denstedt JD, et.al, 2001, Shao Y, et.al, 2008]. Ureteral stenting after uncomplicated ureteric procedures is not a routine during the current study.

URS and laser lithotripsy have proved safety even where ESWL is likely to fail or contraindicated. Major complications are not common during the procedure [Lee H, Teichman JM, et.al, 2003, Alan J. Wein, et.al, 2016]. Minor intra operative complications in the current study were (11.76%) and consist primarily of bleeding and ureteric mucosal injury. Ho: YAG laser related complications are as low as 1% [Markus J. Bader, et.al,2015, Sofer M,et.al,2002, Tawfiek ER,et.al,1999, Alan J. Wein,et.al,2016] and high rate13% [Wael Y Khoder,et.al,2014]. There were no major complications observed in the current series.

Ho: YAG laser light is mainly absorbed by tissue water, so that it has a mean optical penetration depth of 0.2 mm. The mechanism of its laser induced effect for lithotripsy includes the "Moses" effect, (bubble formation in front of stones) and thermal vaporization of the stone water, thus during expansion fragmentation occurs. This mechanism is accompanied with small fragments and many pulses had to be applied, compared to short pulsed lasers (e.g. Q-switch) which produce large fragments in response to fewer pulses. The later laser lithotripsy is attributed to the shock wave effect of the laser resulting from cavitation-collapse mechanisms [Ronald S, et.al, 2012]. Thus with using Ho: YAG laser pulses, the repulsion effect is reduced compared to the short-pulse laser lithotripsy [Ronald S, et.al, 2012]. There are some limitations of the current study. First, include small patients' series, single institution and the lack of randomization, Larger randomized series may be necessary to confirm the long-term efficacy of this procedure. In addition, there is no excess time for fallow up the cases.

Conclusions

Ho:YAG laser lithotripsy is standard in treating ureteric calculi located in the upper, mid and lower ureter. It is able to fragment ureteric stones of all known composition and has an excellent safety profile.

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تفتيت حصى المجرى البولي بوساطة الهولميوم : ياك (2100 نانو ميتر) ليزر

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الخلاصة : يعتبر تفتيت حصى الكلى طريقة معتمدة ثابتة وتوسعت بأستخدام ليزر الهلوميوم (2100 نانومتر) ليتم به معالجة الحصى ذات الاحجام الكبيرة في الجهاز البولي . الهدف من الدراسة: لتقييم فعالية وامان استخدام ليزر الهولميوم للطول الموجي (2100 نانو متر)في تفتيت الحصى بأستخدام ناظور الحالب شبه الصلب لحصى الحالب في دراسة جماعية حالية تتضمن (17مريض) المواد وطريقة العمل: تم استخدام ليزر الهولميوم (2100 نانو متر)في تفتيت الحصى بواسطة ناظور الحالب شبه الصلب ل (17 مريض) ما بين شهر ايلول الى كانون الاول 2016 وجد ان الحصى في الجزء الاسفل من الحالب في(9 مرضى) بنسبة (52.9 %) ، الجزء الاوسط من الحالب في (5 مرضى) بنسبة (29.4 %) والجزء الاعلى من الحالب في (3 مرضى) بنسبة (17.64%) المقاييس التي استعملت كانت: القوة(20 واط)،طاقة النبضة (1.5- 2 جول) ،عرض النبضة (75 – 100 ملي ثانية)،التردد(10 هيرتز) ومقطع الليف البصري(0.55 ملميتر). النتائج : كان المعدل العام للخلو من الحصى (100 %)، للمرضى اللذين يعانون من حصى في الجزء الاسفل(9 مرضى)، الجزء الاوسط(5 مرضى) و الجزء الاعلى من الحالب(3 مرضى). المضاعفات حدثت في مريضين بنسبة (11.76 %) فقط. معدل الزمن اللازم لاجراء عملية تفتيت الحصى كان(34.9 دقيقه). الاستنتاج: تفتيت الحصى بأستخدام ليزر الهولميوم(2100 نانو ميتر) وباستخدام ناظور الحالب يعتبر ذات فعالية عالية وامينة في معالجة حصى الحالب