Outcomes and Efficiency of Thulium Fiber Laser for Ureteroscopic Treatment of Renal Calculi in a Rural Community Hospital in North America

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INTRODUCTION

The prevalence of renal calculi has tripled from 3.8% in the late 1970s to 11% in 2022 in the United States, making it a growing public health concern. Renal calculi are the most common cause of hematuria and abdominal, flank or groin pain. They affect one in eleven people at some point in their lifetime, with men being more commonly affected than women. The recurrence rate for patients with a previous history of urinary stones can approach 50% at ten years. Urolithiasis is more common in Caucasians than African Americans. The "stone belt region" (Southeast and Southwest United States) has a higher incidence due to the hot weather and relative dehydration in these areas.

Several factors can contribute to urinary stone formation, including anatomic variation, urinary stasis, low urine volume, dietary factors, urinary tract infections, systemic acidosis, medications, or genetic factors. Inadequate hydration and subsequent low urine volume are the most common causes of stone disease. Hypercalciuria, hyperoxaluria, hyperuricosuria, and hypocitraturia are other contributing factors.

Diagnosis of urolithiasis requires a urinalysis to identify the presence of urinary crystals or infectious mediators, and a non-contrast abdominal and pelvic CT scan is the most reliable test to diagnose urolithiasis. Acute management involves IV hydration, analgesia, and antiemetic medications, and smaller stones can often pass on their own. Elective surgical removal may be an option, with different procedures available depending on the size and location of the stones. Laser lithotripsy has become a popular choice among urologists, with the thulium fiber laser (TFL) being a promising new technology for lithotripsy with several advantages compared to the previously used Holmium:yttrium-aluminum-garnet (Ho:YAG) laser.

The present study aimed to assess the outcomes and efficiency of the new thulium fiber laser in renal calculi lithotripsy. This is the first study that delves into the efficiency and outcome of the TFL in rural community hospitals.

METHODS

A retrospective medical chart review was conducted in a rural community hospital. We evaluated all patients who underwent laser ureteroscopy from 2020-2022. The medical record of patients meeting the following criteria were selected for the study: patient who had renal calculi and who underwent laser lithotripsy. Medical record of patients who were excluded from this study were patients who did not have renal calculi treated with laser lithotripsy. The consent of individual participants was not required for this study, as it was conducted using data from medical records that did not include participants' personally identifiable information. The following items were collected through medical records: age, sex, BMI, stone location, stone size, stone volume, stone score, presence of preoperative stent, presence of hydronephrosis, total procedure time, laser time (min), laser setting used, basket used or not, operator duty cycles, ablation speed, ablation efficiency, fiber size, used of access sheath, length of stay at hospital, need for admission, post-op ER visit, ureteral injuries, complications, post-op stent use, stent duration, 6-week post-op visit, post-op imaging and any residual stones.

RESULTS

The study included 41 patients with renal calculi measuring 10-30 mm and a median age of 55 years. The stones were primarily dusted using settings of 0.5J and 70Hz, with a mean laser ablation speed of 3.98 mm3/sec and ablation efficiency of 0.02J/mm3. Most cases showed good dusting. Seven patients with stones larger than 2 cm were successfully dusted, achieving complete clearance. Intraoperative complication included Grade 1 mucosal ureteral injury in two patients and Grade 3 ureteral injury in one patient. However, all complications healed completely after stenting for 3 weeks. Postoperative imaging (renal ultrasound at six-week post-op) was completed by 31 patients, with 28 showing complete clearance.

Table 1:
Patient's demographics

Variable	Results
Age (Mean ± SD) years	55.2 ±17.5
Gender	
Female	28 (64)
Male	16 (36)
BMI (Mean ± SD)	32.9 ± 8.7

Note. (#)= Percentage

Table 2:
Stone Demographics characteristics, preoperative data

Variable	Results
Stone Size (mm)	
<10	29
10-19	10
20-30	2
>30	1
Stone Volume (mm^2)	
10-19	24
20-30	8
>30	2
STONE Score	
3	10
4	4
5	8
6	5
7	2
8	3
9	0
10	2
11	1
Stone Location	
Pelvic	2
Lower calyx	13
Middle calyx	10
Upper calyx	11
UPJ	3
Mixed calyces	5
Stone number	
Isolated	29 (65.9%)
Multiple	15 (34.1%)
Preoperative stent	
Yes	13
No	31
Presence of hydronephrosis	
Yes	16
No	28

Table 3:
Intraoperative, postoperative, and laser data

Operative time (minutes)	56.98
Use of ureteral access sheath	24 (54.5%)
Use of basket	13 (29.5%)
Laser time (min)	
Laser setting used	
Total energy of laser	
Laser ablation speed (mm^3/sec)	3.98
Ablation efficiency (J/mm^3)	0.02
Fiber Size	
200	28
272	4
1000	1
Postoperative stent	37
Postoperative imaging	1
Stent Duration (days)	13.1 ± 20.7
Complete Clearance	28

Table 4:
Intraoperative and Postoperative complications

Intraoperative	
Bleeding	2
Dilation for access	1
Mucosal ureteral injury	
Grade 1	2
Grade 3	1
Difficult entry	5
Postoperative	
Residual stones	3

DISCUSSION

In the present study, the findings indicate that TFL has an overall better prognosis and with its capability it can be used in rural community hospitals.

The Ho: YAG laser became gold-standard due to several reasons. In comparison to other laser lithotripsy at that time, the Holmium: YAG laser was (1) suitable for fragmentation of all known urinary stone types into small stone particles; (2) able to operate with thin and flexible delivery fibers with limited energy losses and with core diameters as small as 200 um; (3) favorable safety profile with minimal tissue penetration depth and low risk of undesirable tissue damage due to relatively high absorption coefficient of the Ho: YAG laser wavelength in water; (4) versatile which allows a Ho: YAG laser system to be used for soft tissue application additionally to stones, which partially offsets the costs of high-power systems.

However, there has been increasing interest in a new thulium fiber laser (TFL) that launched in 2018. According to some authors, it seems to be one of the most promising new laser technologies for lithotripsy with several advantages compared to the Ho: YAG laser (Kronenberg).

Several studies have indicated that the Thulium fiber laser surpasses Ho: YAG laser in many aspects. TFL is (1) able to ablate a significantly higher stone volume; (2) uses a lower energy setting; (3) less prone to retropulsion. When comparing technical aspects of each laser, pulse frequency of up to 2200 HZ compared to 30 Hz in Ho: YAG, pulse energy can range from 0.005 J to 6J whereas in the Ho: YAG the minimum energy is 0.2 J. Having access to low energies is important, especially performing a dusting procedure, as they could help obtain the smallest dust particles possible and keep retropulsion to a minimum. In addition, TFL has a peak power of 500 W compared to 140 W in the most recent and powerful Ho: YAG laser.

The TFL has been reported to offer a better endoscopic view during lithotripsy. The reduced retropulsion and consequent reduced medium turbulence could be responsible for this, as fewer fragments and dust particles are swirled up, thereby reducing the "snowstorm" effect that is characteristic of Ho: YAG lithotripsy. By producing less retropulsion, the TFL is also more readily operated by less experienced users, reducing the learning curve and the need to constantly adapt to a persistently changing stone position.

Despite the TFL's technical better performance, the TFL machines are seven times smaller and eight times lighter where they can fit inside an endoscopy tower/cart along with other electronic equipment and devices. In addition, it consumes almost 10 times less electricity, has higher wall-plug efficiency, has no specific electrical installation of the OR, and has fewer laser-fiber-related costs. Finally, TFLs are less likely to cause radiation and electrical hazards, have low noise levels, and provide a greater safety margin from accidental perforation of tissues or damage to instruments during laser irradiation.

CONCLUSION

This initial series of the use of SP-TFL has shown promising results. This laser doesn't need high power outlets hence was easy to operate in any operating room in our community hospital. Further prospective comparative trials with long term follow up are needed to establish supremacy over the holmium laser.

CONTACT

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