Holmium laser: YAG lithotripsy in ureteral calculi management

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Abstract. This study determined the predictive factors for the success of holmium:YAG laser lithotripsy in ureteral calculi management. This prospective cohort study was conducted from January 2013 to May 2015 at Kardinah Hospital, Tegal, Central Java. 50 patients diagnosed with proximal (13, 26%) and distal (37, 74%) ureteral stones were included in this study. Stone burden, duration of operation, and number of ureteral calculi were predictive factors for the success of holmium:YAG laser lithotripsy in ureteral calculi management.

1. Introduction

Ureteral calculi management has been rapidly growing in the last decade. Ureterolithotomy is the prior treatment for management of ureteral calculi [1,2]. Simple urologic endoscopy began to be performed since 1806 and has developed increasingly. The development of ureteroscopy appliances and other smaller endoscopy instruments provided better calculi fragmentation, more efficient calculi evacuation, a greater number of free calculi, and lower morbidity rates compared with open surgery [3]. Currently, ureteroscopy uses a sophisticated, smaller caliber lithotriptor, such as ultrasound, pneumatic, electrohydraulic, neodymium:YAG laser, pulsed dye laser, and the latest holmium:YAG laser lithotripters [3–5].

Rigid ureteroscopy was reported by Young and McKay in 1929 to develop an instrument for retrograde access to the upper urinary tract. The first rigid ureteroscope was not used routinely until 1977, when Goodman et al. demonstrated its appliance security. Semirigid ureteroscopy then continued to develop and Marshall introduced flexible ureteroscopy in 1964. Ureteroscopy is performed not only for diagnosis but also for therapy [6].

Holmium laser is a type of laser used for various medical purposes, including urological purposes. Holmium laser combines the CO2 laser as a cutter and neodymium laser as a coagulant, which is used frequently in surgery. The holmium laser can be transmitted through the fiber and absorbed by the water, which is suitable for use in endourological procedures. It is also used frequently in other disciplines, such as prosthetic aids, ophthalmology, otolaryngology, cardiology, and oral maxillofacial surgery [7].

Urological use of the holmium laser includes incision of the ureters or urethra, bladder tumor ablation, prostate resection, and lithotripsy (first reported in 1995 [7]). Many studies report the high
effectiveness and security of this method. The holmium:YAG laser is superior for ureteral calculi fragmentation, and it has become the choice of lithotriptor for many urologists worldwide. Few reports exist of holmium:YAG laser use in Indonesia. Therefore, we determined the factors that affect the success of holmium:YAG laser lithotripsy on ureteral calculi.

2. Methods
This prospective cohort study was conducted in patients with proximal and distal ureteral calculi to determine the predictive factors that affected the success of holmium:YAG laser lithotripsy. The study protocol was approved by the Health Research Ethics Committee, Faculty of Medicine, Universitas Indonesia-Cipto Mangunkusumo Hospital. The study was conducted from January 2013 to May 2015 at Kardina hospital in Tegal, Central Java. Of all ureteral calculi patients who underwent ureteroscopy, we studied 50 (average age, 42.94 ± 11.31 years; 28 [56%] males, 22 [44%] females) who underwent holmium:YAG laser lithotripsy.

Samples were obtained from all patients via a total sampling method. Clinical data were collected at operation using a semirigid ureteroscope (Wolf) size 6/7.5F, video monitor, and holmium:YAG laser lithotriptor (Versa Pulse, Lumenis, Germany) with 2100 nm wavelength, 1–60 watts output, and 365 μm fiber. The strength of the laser ranged from 2.5–10 watts with exodus energy ranging from 0.5–1 J at 5–15 Hz. All procedures were performed by a urologist and senior residents with the patient under regional anesthesia. The laser fiber was positioned in contact with the ureteral calculi, facilitated by helium-neon red rays. The laser fiber did not contact ureteral mucosa. Radiologic evaluation was used to assess for retained ureteral calculi 1 month after ureteroscopy.

Bivariate analysis was done to assess the mean difference between each variable in the holmium:YAG laser lithotripsy group, such as retained ureteral calculi, using t-tests, and Mann–Whitney U and χ² tests. Data were analyzed with SPSS 15.0 software (SPSS, Inc., Chicago, IL, USA).

3. Results
Of the 50 study patients, 13 had proximal (26%) and 37 had distal (74%) calculi. The average stone burden was 88.10 ± 57.41 mm² (Table 1).

| Variables                        | Value                           |
|----------------------------------|---------------------------------|
| Median age ± SD (years)          | 42.94 ± 11.31 (39.5)            |
| Sex                              |                                 |
| Male                             | 28 (56.0%)                      |
| Female                           | 22 (44.0%)                      |
| Ureteral calculi position        |                                 |
| Proximal                         | 13 (26.0%)                      |
| Distal                           | 37 (74.0%)                      |
| Median stone burden ± SD (mm²)   | 88.10 ± 57.41 (79.29)           |
| Number of calculi                |                                 |
| Single                           | 44 (88.0%)                      |
| Multiple                         | 6 (12.0%)                       |
| Median operative time ± SD (minutes) | 19.02 ± 21.17 (12)             |
| Median energy ± SD (J)           | 1079.02 ± 1624.00 (540)         |
| Installation of the DJ stent     | 41 (82.0%)                      |
| Stone-free rate                  | 90.00%                          |
| Additional actions               | 4 (8%)                          |
Average energy use for ureteroscopy was approximately 1079.02 ± 1624.00 J, and operative time was approximately 19.02 ± 21.17 minutes. A double-J (DJ) stent was installed postoperatively in 41 (82%) patients. Procedure failure, such as ureteral calculi migration to the kidneys and conversion to open surgery, occurred in 2 patients (4%). The stone-free rate after holmium:YAG laser lithotripsy was 90%.

### Table 2. Bivariate analysis based on the retained ureteral stone

| Variables                        | Retained ureteral stone | p value |
|----------------------------------|-------------------------|---------|
| Age, X ± SD                       | Absent | Present |         |
| Sex, n (%)                        |         |         |         |
| Male                             | 24 (85.7) | 4 (14.3) | 0.254#|
| Female                           | 21 (95.5) | 1 (4.5)  |         |
| Ureteral calculi, n (%)           |         |         |         |
| Proximal                         | 12 (92.3) | 1 (7.7)  | 0.747#|
| Distal                           | 33 (89.2) | 4 (10.8) |         |
| Stone burden, mm²                | 81.48 ± 53.41 | 147.69 ± 63.74 | 0.013*|
| Number of calculi, n (%)          |         |         |         |
| Single                           | 43 (97.7) | 1 (2.3)  | 0.000#|
| Multiple                         | 2 (33.3) | 4 (66.7) |         |
| Operative time, minutes          | 18.16 ± 21.73 | 26.8 ± 14.51 | 0.038§|
| Energy, J                        | 1081.24 ± 1169.56 | 1059.00 ± 870.48 | 0.438§|

* t-test, # χ² test, § Mann–Whitney U test.

Bivariate analysis was done on each variable whether the ureteral stone was absent or present after holmium:YAG laser lithotripsy. Mean differences in stone-free rates were obtained between stone burden (P = 0.013), operative time (P = 0.038), and number of calculi (P = 0.000). The differences in stone-free rates between age, sex, ureteral calculi position, and energy were not significant (Table 2).

### 4. Discussion

In the last decade, laser use has increased in intracorporeal lithotripsy, with the holmium:YAG laser used most frequently. The holmium:YAG laser has become very important due to the high success and patient comfort rates, low morbidity and complication rates, and short hospitalization. With these advantages, holmium:YAG laser is the choice for management of ureteral calculi [7,8,9].

Our overall stone-free rate after holmium:YAG laser lithotripsy was 90%, which was identical to that in previous studies. Previous studied reported stone-free rates of 95.1%, 97%, 95.8%, and 90.9%, respectively [4,9,10]. In our study, stone burden, operative time, and number of ureteral calculi influenced the stone-free rate, whereas age, sex, ureteral calculi position, and energy did not.

The stone burden affected the success of the procedure. Stone burden was in greater cases with retained ureteral calculi after ureteroscopy. Similarly, Khoder et al. [10] also found that stone burden and diameter of the largest stones affected the success rate of ureteroscopy with holmium:YAG laser lithotripsy. Meanwhile, another study showed different results. Leitje et al. [2] reported no relationship between ureteral calculi size and success of ureteroscopy with the holmium:YAG laser. This result can be caused by differences in ureteral calculi composition, types of tools used, and skill of the operator [2,6,11,12].

Operative time also affected the stone-free rate. Shorter operative times were obtained in stone-free patients after effective holmium:YAG laser lithotripsy. Biyani et al. reported a 97.9% stone-free rate
after an average 46-minute operative time. Multiple ureteral calculi were observed in patients with retained calculi after holmium:YAG laser lithotripsy [13]. Raza et al. reported that the repeat ureteroscopy rate is higher in patients with multiple ureteral calculi [11].

The age and sex of patients did not affect the success of holmium:YAG laser lithotripsy in our study. Other studies show similar results. Leitje et al. reported no effect of age and sex on the success rate [2].

Our study showed a significant difference in stone-free rate between proximal (92.3%) and distal (89.2%) ureteral calculi. Leitje et al. reported a lower stone-free rate in the proximal (78.6%) compared with distal (88.1%) ureters whereas Sofer et al. reported a higher stone-free rate (97% vs. 98%, respectively) [2,9].

The energy required for holmium:YAG laser lithotripsy showed insignificant differences regarding stone-free rate. In our study, more energy was used in patients with larger ureteral calculi because their large size could reduce the risk of tissue injury caused by the laser. The energy used for each type of ureteral calculus also was different. Previous study reported a greater amount of energy for struvite, brushite, uric acid, cysteine, and monohydrate calcium oxalate stones (2.74, 5.81, 4.83, 5.81, and 6.02 J/mg, respectively) [14].

A DJ stent was installed postoperatively in 41 patients (82%). Installation of the DJ stent, which is indicated for long lithotripsy procedures, impacted ureteral calculi, ureteral mucosa laceration, and solitary kidneys [15]. Yip et al. [8] reported installation of a DJ stent in 83% of cases [8]. Sofer et al. and Denstedt et al. reported that installation of the DJ stent did not influence the stone-free rate. Use of a holmium laser lithotriptor did not routinely require installation of a DJ stent. [9,15].

Our study demonstrated two cases (4%) of failure during surgery, such as migration of ureteral calculi to the kidneys and conversion to open surgery (ureterolithotomy). The difficulties during surgery were due to hydronephrosis and heavy hydroureter with proximal ureteral calculi. Ureteroscopy caused the ureteral calculi to be pushed into the kidneys and they could not be retrieved [8].

In general, we reported high stone-free rates after semirigid ureteroscopy with the holmium:YAG laser lithotriptor. Therefore, the holmium:YAG laser lithotriptor is a good choice for ureteral calculus management.

5. Conclusion

Treatment of ureteral calculi with holmium:YAG laser lithotripsy resulted in a 90% stone-free rate. Stone burden, operative time, and number of ureteral calculi were factors affecting the success of holmium:YAG laser lithotripsy. Meanwhile, age, sex, ureteral calculus position, and energy had no effect on the success of this procedure.

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