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ORIGINAL RESEARCH

Do Stone Characteristics and Laser Fiber Size Affect Ho: YAG Laser Time and Energy During Ureteroscopy?

Abdihamid Hassan Hilowle[1], Abdikarim Hussein Mohamed[2]

[1]Urology Department, Mogadishu Urological Center, Mogadishu, Somalia; [2]Urology Department, University of Somalia, Mogadishu, Somalia

Correspondence: Abdikarim Hussein Mohamed, Tel + 252615167182, Email abdikarimgabeyre@gmail.com

Objective: To assess the correlation of attenuation value measured as HU in Non-contrast computed tomography, stone size, location, fibre size and stone composition with Holmium: yttrium-aluminium garnet (Ho: YAG) laser parameters including, cumulative laser energy and final laser time.

Materials and Methods: We prospectively analyzed 118 patients undergoing flexible/semirigid ureteroscopy and Holmium: YAG laser lithotripsy from October 2022 to October 2023 at Mogadishu Urological Centre. Our study parameters encompass preoperative stone characteristics determined in NCCT (stone size, attenuation value, and stone location), fibre size, cumulative laser energy and time, overall operative time, and postoperative stone composition analysis.

Results: There were 118 patients eligible for our prospective study. In the logistic regression model for retrograde intrarenal surgery with a fibre size of 272 µm, cumulative laser energy showed a significant difference among stone size, location, fibre size, and calcium oxalate stones ($P > 0.05$). However, no significant difference was noticed in the attenuation value ($P = 0.078$) ($R2 = 0.053$). Our analysis showed a positive significance among all the parameters ($P < 0.05$) for laser time. In logistic regression for a rigid ureteroscope with a fibre size of 365 µm, cumulative laser energy showed a significant difference between the location stone and fibre size ($P < 0.05$) ($R2 = 0.09$). However, no significant difference was seen among stone size, attenuation value, and calcium oxalate stones ($P > 0.05$). For laser time, our analysis showed a positive significance among all parameters except the calcium oxalate stones, which showed no significant difference ($P > 0.05$).

Conclusion: Our study showed that stone location, hardness, and fibre size are the most critical factors influencing the outcome of Ho: YAG laser parameters. The study revealed that CaOMH stones require more time to disintegrate into smaller ones, while PH-dependent stones such as carbonate apatite may require less time to fragment.

Keywords: stone size, attenuation, stone density, Ho: YAG laser, cumulative laser energy

Introduction

Urinary stone disease is a common urological disorder whose prevalence varies between 2% and 20% worldwide.[1] Over the last decade, the treatment option for upper urinary stones has shifted from open surgery to shock wave lithotripsy and minimal invasive procedures, such as percutaneous nephrolithotomy, ureteroscope, and laparoscopic techniques.[2] The invention of semirigid/flexible ureteroscopes with the introduction of the Holmium: yttrium-aluminium-garnet (Ho: YAG) laser has increased in stone-free status while sustaining a low mortality rate.[3]

Non-contrast computed tomography (NCCT) has emerged as the most appropriate and sensitive diagnostic tool while providing crucial information for treatment planning.[4–6] As previous studies reported, NCCT gives precise information on stone characteristics such as size, location, and depth and predicts the stone's hardness by measuring stone density in the Hounsfield unit. Hence, many studies investigated the correlation of HU in NCCT with stone composition and proposed the ability to predict the efficiency of ESWL and the stone-free status of URS and percutaneous nephrolithotomy.[7–10] A few studies investigated the impact of the stone dimensions, hardness, stone location, fibre size, and power on Ho: YAG laser

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cumulative energy and total time.[11] There is no previous study regarding the impact of stone parameters on Ho: YAG laser cumulative energy and laser time reported from Somalia.

This study aimed to assess the correlation of preoperative evaluation of NCCT stone characteristics, stone composition, fibre size and stone composition with laser parameters, including cumulative laser energy and laser time.

Materials and Method

Between October 2022 and October 2023, we prospectively analyzed 118 patients undergoing flexible/semirigid ureteroscopy and Holmium: YAG laser lithotripsy (raykeen laser technology) at the Mogadishu urological centre. Our study inclusion criteria are the presence of renal/ureteral stone on an adequate preprocedural KUB radiograph and NCCT scan. We included patients more than 18 years of age with stone size >0.5cm in diameter. Patients going through the URS procedure for the first time or were given URS as the first stage in multistage URS procedures were also included in our study. Our exclusion criteria encompass patients with inadequate analysis parameters such as incomplete preoperative imaging assessment, incomplete intraoperative data, inadequate stone analysis, and stone fragmentation methods besides Holmium: YAG laser lithotripsy, patients with renal stones larger than 2.5cm, and sponge kidney were excluded from our study. Also, patients with URS history (more than two stages of URS) were excluded.

Surgical Technique

All patients were given intravenous preoperative antibiotics. Before the commencement of the treatment procedure, patients are placed in a dorsal lithotomy position and covered in a sterile fashion under anaesthesia. After the patient's positioning, the cystoscope is inserted into the patient's bladder through the urethra; this allows surgeons to visualize the ureteral orifice. The 22.5 F is cannulated with an open-end 5F catheter and a 0.038-inch hydrophilic guidewire. For direct visualization, a 6/7.5F or 8/9.8F semirigid ureterorenoscopy (Wolf, TM Knittlingen, Germany) is passed over a guidewire until it reaches the proximal ureter or renal pelvis. All this is done using fluoroscopic guidance.

Investigated parameters included stone characteristics, stone composition, fibre size, stone composition, and laser parameters, including cumulative laser energy and laser time.

Ethical Approval

The study was performed following the declaration of Helsinki guidelines and regulations. Mogadishu Urological Center review boards approved the study protocol (REF NO. MUC3278), and all participants provided written informed consent.

In statistical analysis, excel 2007 (Microsoft, Redmond, WA, USA) and IBM SPSS software v20.0 (IBM Corp. released 2011. IBM SPSS Statistical for Windows, version 20.0. Armonk, NY: IBM Corp) were performed for our data analysis. All continuous variables were determined as mean ± standard deviation. Independent sample *T*-test was used to compare the two groups. A logistic regression analysis model was performed to find the correlation of stone characteristics determined in NCCT, surgical parameters and postoperative stone composition analysis with cumulative laser energy and laser time.

Results

Descriptive analysis

The demographic details and surgical outcomes:

According to our inclusion criteria, a total of 118 patients (55 females and 63 males) were eligible for our prospective research. The mean patient age was 36.2 ± 9.7 years. Eighty-four patients were diagnosed with single stones, and 34 patients appeared with multiple stones. Overall mean stone density was reported as 944 ± 378 HU with mean stone size of 1.3 ± 0.28cm. The overall surgical duration among these patients was reported to be 52.8 ± 30.18 minutes; any surgeries beyond 120 minutes were halted. The most commonly reported stone location was at the proximal ureter in 48 patients (41%), followed by intrarenal stone in 34 patients (29%), in which 11 patients presented with lower pole stones. Other stone locations reported were distal ureter in 20 patients (17%) and mid ureter in 16 (13%). The most common reported stone among our patients was 44 cases of calcium oxalate monohydrate (CaOMH) stones (37%). Other stone compositions reported in our patients were 40 cases of calcium mixed stones (34%), 15 cases of calcium oxalate dihydrate (CaODH) stones (13%), 16 cases of UA stones (12%), 3 cases of carbonate Apatite stones (2.5%) and 2 cases of Struvite stones (1.5%).

Independent *T*-test

As shown in Table 1, patients were divided according to their attenuation value (HU value): Group 1 (>1100HU value), group 2 (<1100HU value). Among all these patients, 47 were included in group 1, as they have high attenuation (>1000 HU). The most common location of stones among these patients was the proximal ureter (42%); another most common location for stones in these patients was intrarenal stone (32%). Few patients were reported with a stone location at the distal ureter (15%) and mid ureter (11%). The overall surgical duration of group 1 was reported to be 57.55 ± 27.601 minutes. Group 1 patients showed a stone density marked as 1336.00 ± 161.646 cm3. The most common stone composition in this group was CaOx mono (66%); other stone compositions in this group were mixed stones (30%) and CaOx di (4%). No UA, Apatite or Struvite stones were reported among group 1 patients.

Group 2 included 71 patients who received low-intensity surgical treatment (<1000 HU). The most common location site of stone in group 2 patients was proximal ureter (39%); the second most reported common site was intrarenal stone (27%). Other stone locations reported in this group included the distal ureter (18%) and mid-ureter (16%). The overall surgical duration for group 2 patients was reported to be 49.52 ± 31.553 minutes, and stone density was reported to be 684.49 ± 224.667 cm3. The most common stone composition among group 2 was mixed stones (37%). Another stone composition reported among group 2 patients was UA (20%), CaOx mono (18%) and CaOx di (18%). The least reported stone composition among these patients was Apatite (4%) and Struvite (3%).

In a comparison between the two groups, no significant differences were reported among the location of the stone (P value 0.361), surgical duration (P value 0.866) and stone composition (P value 0.211). Only the stone density between group 1 and group 2 reported a significant difference (P value 0.023) (P value <0.05).

Among all the patients, nine patients were reported to have ureteral stricture during surgery, and two patients were reported to have postoperative fever. No other major complications were noticed.

Logistic regression analysis

We performed the logistic regression model analysis for cumulative laser energy and laser time in patients treated for renal stone and ureter stone with flexible ureteroscope and rigid ureteroscope prospectively. The parameters used for logistic regression analysis were stone size, stone location, fibre size, attenuation value and calcium oxalate against calcium oxalate (Tables 2 and 3). We excluded the patients with rare stone compositions, such as uric acid dihydrate and cystine, as the conclusion would be difficult to be reliable with a single stone composition.

Table 1 Independent Sample *t* Test Were Used for Group Comparison

	Group 1 (>1100HU) (n=47)	**Group 2 (<1100HU) (n=71)**	**P value**
Location of stone			
Intrarenal stone	15	19	0.361
Proximal ureter	20	28	
Mid ureter	5	11	
Distal ureter	7	13	
Overall operative time	57.55±27.601	49.52±31.553	0.866
Stone density	1336.00±161.646	684.49±224.667	0.023
Stone composition			
CaOx mono	31	13	0.211
CaOx di	2	13	
Mixed stones	14	26	
UA	0	14	
Apatite	0	3	
Struvite	0	2	

Table 2 Influence of Renal Stone Treated with Flexible Ureteroscope on Cumulative Laser Energy and Laser Time

	Coef.	95% CI	P value	R^2
Laser energy				
Stone size	16,852.29	12,177.28 to 21,527.31	<0.000	0.4730
Location (renal)	9295.021	5072.169 to 13,517.87	<0.000	0.1408
Fiber size (272 µm)	6717.806	2779.959 to 10,655.65	<0.001	0.0896
Predictive value	8.760578	1.011034 to 18.53219	>0.078	0.0526
Calcium oxalate	8318.933	1551.85 to 15,086.02	<0.017	0.0945
Laser time				
Stone size	12.83879	9.580965 to 16.09661	<0.000	0.5176
Location (renal)	6.538326	−3.654346 to 9.422307	<0.000	0.1481
Fiber size (272 µm)	0.0079821	0.0009778 to 0.0149865	<0.026	0.0823
Predictive value	5.467632	2.821607 to 8.113657	<0.000	0.1262
Calcium oxalate	5.750714	0.7966664 to 10.70476	<0.024	0.0852

Table 3 Influence of Ureteral Stone Treated with Rigid Ureteroscope on Cumulative Laser Energy and Laser Time

	Coef.	95% CI	P value	R^2
Laser energy				
Stone size	3354.445	−576.8698 to 7285.759	0.093	0.0496
Location (ureter)	17,734.8	−24,270.66 to −11,198.94	0.000	0.3454
Fiber size (365 µm)	4.148934	−0.3951693 to 8.693038	0.073	0.0564
Predictive value	−6717.806	−10,655.65 to −2779.959	0.001	0.0896
Calcium oxalate	−510.2664	−4374.965 to 3354.432	0.792	0.0012
Laser time				
Stone size	2.85567	1.697707 to 4.013634	0.000	0.3035
Location (ureter)	−5.167939	−7.578751 to −2.757128	0.000	0.2477
Fiber size (365 µm)	0.0027583	0.0013281 to 0.0041885	0.000	0.2104
Predictive value	−5.467632	−8.113657 to −2.821607	0.000	0.1262
Calcium oxalate	0.5672222	−0.7546928 to 1.889137	0.394	0.0130

For the treatment of renal calculi with the flexible ureteroscope, also known as retrograde intrarenal surgery (RIRS) with Holmium:yttrium-garnet (Ho: YAG) fibre size (272 µm), in our analysis, the cumulative laser energy showed a significance difference among stone size, stone location, fibre size, and calcium oxalate stones ($P > 0.001$), but no significance difference was seen in the attenuation value ($P = 0.078$) ($R2 = 0.0526$). For laser time, our analysis showed a positive significance among all the parameters: stone size ($P = 0.000$) ($R2 = 0.5176$), stone location ($P = 0.000$) ($R2 = 0.1481$), attenuation value ($P = 0.026$) ($R2 = 0.0823$), and calcium oxalate stone ($P = 0.001$) ($R2 = 0.085$). Using a fibre size of 272µm, both attenuation value and fibre size can influence the laser time. However, no differences were noted between attenuation value and cumulative laser energy.

Calcium oxalate stones can influence the outcome of cumulative laser energy and laser time (Table 2).

For the treatment of ureter stone with rigid ureteroscope with Holmium:yttrium-garnet (Ho: YAG) fibre size (365µm), our analysis the cumulative laser energy showed a significance difference between the location stone ($P < 0.001$) (($R2 = 0.35$) and fibre size ($P = 0.001$) ($R2 = 0.09$), but no significance difference was seen among stone size ($P > 0.001$) ($R2 = 0.05$), attenuation value ($P = 0.073$) ($R2 = 0.056$) and calcium oxalate stones ($P = 0.792$) ($R2 = 0.0012$). In the event of laser time, our analysis showed a positive significance among all parameters (stone size $P > 0.001$: $R2 = 0.305$, stone location $P < 0.05$: $R2 = 0.248$, fibre size $P < 0.05$: $R2 = 0.1262$ and attenuation value $P < 0.05$: $R2 = 0.2104$), except the calcium oxalate stones, which showed no significance difference (P = 0.394) (R2 = 0.013). Our results suggested that the stone size, fibre size and predictive value influence the laser time for a rigid ureteroscope. The calcium oxalate stone did not influence the cumulative laser energy and time (Table 3).

Discussion

The invention of better instrumentation, such as Ho: YAG, revolutionized laser technology and became the reference standard for the URS technique. Furthermore, it is shown to have the capacity to fragment any stone composition through a photothermal mechanism.[11–13] When Ho: YAG energy is applied, it increases the local stone temperature to a maximum thermal threshold, causing the stone components to be eliminated using vaporization, dissolving, decomposing and converting into different products.[12,13]

Our results revealed a positive correlation between laser fibre size and cumulative laser energy. Recent studies report that a larger fibre size tends to have higher energy expenditure than a smaller one. Hence, smaller fibres, such as 200-µm, contain a silica mixture, which is more likely to be damaged, resulting in poor energy transmission.[13,14]

Apart from fibre size, several factors, such as stone size, composition, and stone density, determined in NCCT, have shown the ability to alter the cumulative laser energy.

In the event of laser time, our purpose was to focus on the effect of stone features on laser parameters. During our study, we found that fragmentation of renal stones consumes more time when compared with ureteral stones. The reason for firing more pulses inefficiently for the treatment of kidney stones than ureter stones is that the mobility of the stone in the kidney is typically higher than in the ureter; this causes the total contact time between the tip of the laser and the calculus to be minimized. Most studies investigated the overall operative time instead of the time needed to fragment the stones into smaller pieces. Hence, overall surgical time encompasses several surgical steps: surgeon's experience, process of access to the stone such as passage of calculi, ureteral sheath, use of flexible/rigid URS, stone fragmentation, extraction, and postoperative stent. Therefore, this indicates that overall surgical time is not only affected by stone features but also anatomical structures and the location of the calculi.

We investigated the influence of attenuation value measured as HU in NCCT on laser time and found a positive correlation with Ho: YAG cumulative laser energy and laser time. Molina et al evaluated the effect of the attenuation coefficient on laser parameters and found a positive correlation between maximum and minimum attenuation coefficient and laser parameters.[13] Our results correspond to these findings and reveal the association between those parameters. Therefore, we concluded that a high attenuation coefficient demands high laser requirements, whereas a low attenuation coefficient demands fewer. Previous studies evaluated the ability of the attenuation coefficient determined in NCCT to predict stone hardness and assessed it as a direct prediction of ESWL outcome and stone-free rate after URS and percutaneous lithotomy.

Furthermore, harder stones are typically associated with poor ESWL outcomes.[9,15] In this study, we divided patients into two groups according to their attenuation value measured in NCCT with the consideration of (1100 HU) as their medium cutoff point for each group and investigated the utility of maximum and minimum attenuation coefficient (HU) in NCCT as a predictor of operative time after URS procedure. However, the results did not show any correlations regarding those findings. Similarly, Ito et al investigated the role of the attenuation coefficient on fragmentation efficiency and found that both high and low attenuation values were significantly related to fragmentation efficiency. Estimating maximum and average attenuation coefficients in NCCT determines the stone fragility, representing fragmentation efficiency during the URS procedure.[10]

The strong correlation between the HU value determined in NCCT and stone composition was frequently reported. Furthermore, few reports looked into lithotripsy efficiency and noticed its variation in stone compositions.[15] Regarding the rationale of URS, it is postulated that stone composition was a significant indicator of laser lithotripsy time rather than the attenuation coefficient. A study on the influence of stone composition on laser lithotripsy was conducted by Molina et al in 2013. He suggested that CaPH stones were more accessible to be fragmented with a Ho: YAG laser, whereas the CaOMH and UA stone fragments showed no difference. Our results were partially similar to those obtained in this study. Our results showed that the CaOMH stone affects the cumulative laser energy and time. This reason for our results could be the high number of patients treated at our hospital with these particular stone types, calcium mixed stones and CaOMH. The Ho: YAG lithotripsy has different effects for every stone type in vitro.

When the laser fibre and energy are held stable, the depth and width of stone craters are lowest in ascending order for CaOMH, UA, CaPh and infectious stones, respectively. The CaOMH has the highest melting point temperature of more than 204°C. The UA and CaPh stones both breakdown at a temperature above 100°C. The infectious stones have the lowest temperature point as they desiccate at 100°C. After a breakdown, the crates of CaOMH stones are much smaller than the UA, CaPh and infectious stones. Teichman et al suggested an explanation for different laser energy absorption for different stone compositions; he suggested that different stones have different water compositions, and the peak wavelength absorption of water is most effectually close to the Ho: YAG wavelength.[16,17] Hence, every stone differs in its melting point. However, their study did not investigate the percentage for each component in the stone, as extremely heterogenous calculi can also suggest a reason for a high wavelength. A recent investigation from the same centre conducted the study, suggesting that the comparable crater volume between CaOMH and UA stones differs from their previous study.[18,19]

Our study has several limitations, included the small sample size in stone composition, especially the limited number of stones such as uric acid stones, carbonate apatite, struvite and cysteine. This, however, may have potentially influenced the outcome of the study, and also, we were unable to record the time to retrieve the stones, although our study was a prospective study. Another limitation is that we could not obtain a follow-up radiological confirmation for a stone-free rate. Further large prospective studies are needed to explore the impact of laser parameters on different modules of power and Moses technologies.

Conclusion

Cumulative laser energy and laser time of Ho: YAG laser lithotripsy are affected by the stone size, attenuation value measured as HU in NCCT, fibre size, stone composition, location and power of the laser. Furthermore, our study showed that stone location, fibre size and hardness are the most critical factors influencing the outcome of Ho: YAG laser parameters. Regarding stone composition on laser parameters, harder stones such as CaOMH require more time to be disintegrated into smaller ones. In contrast, PH-dependent stones such as carbonate apatite may require less time to be fragmented.

Data Sharing Statement

All study data and materials can be obtained from the corresponding author.

Ethical Approval

The study was performed following the declaration of Helsinki guidelines and regulations. Mogadishu Urological Center review boards approved the study protocol (REF NO. MUC3278).

Informed Consent

Informed consent was obtained from all patients.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declared no competing interests.

References

1. Rendina D, D'Elia L, Evangelista M. et al. Osteoporosis is a predictive factor for nephrolithiasis in an adult free-living Caucasian population from southern Italy: a longitudinal retrospective study based on a general practice database. *Calcified Tissue International*. 2020;107(5):446–452. doi:10.1007/s00223-020-00737-9
2. Abbagani S, Gundimeda SD, Varre S, Ponnala D. KIDNEY STONE DISEASE: ETIOLOGY AND EVALUATION. *International Journal of Applied Biology and Pharmaceutical Technology*. 2010;I(1):175–182.
3. Yaycioglu O, Guvel S, Kilinc F, et al. Results with 7.5F versus 10F rigid ureteroscopes in treatment of ureteral calculi. *Urology*. 2004;64 (4):643–646. doi:10.1016/j.urology.2004.05.050
4. Arslan E, Mohamed AH. Evaluation, management, and analysis of demographic and radiological characteristics of patients with renal colic at a tertiary hospital in Somalia. *Afr J Emergency Med*. 2022;12(4):358–361. doi:10.1016/j.afjem.2022.07.011
5. Cimen S, Eraslan A, Mohamed AH, et al. Clinical characteristics and short-term outcomes of adult patients with urolithiasis: first report from Somalia. *EurRev Med Pharmacol Sci*. 2023;27(15):1.
6. Semins MJ, Bartik L, Chew BH, et al. Multicenter analysis of postoperative CT findings after percutaneous nephrolithotomy: defining complication rates. *Urology*. 2011;78(2):291–294. doi:10.1016/j.urology.2010.11.008
7. Jansen ED, van Leeuwen TG, Motamedi, M, Borst, C, Welch, AJ. Temperature dependence of the absorption coefficient of water for midinfrared laser radiation. *Lasers in Surgery and Medicine*. 1994;14(3):258–268.
8. Sea J, Jonat LM, Chew BH, et al. Optimal power settings for Holmium: YAG lithotripsy. *J Urol*. 2012;187(3):914–919. doi: 10.1016/j.juro.2011.10.147
9. Pareek G, Armenakas NA, Panagopoulos G, et al. Extracorporeal shock wave lithotripsy success based on body mass index and Hounsfield units. *Urology*. 2005;65(1):33–36. doi:10.1016/j.urology.2004.08.004
10. Hiroki I, Takashi K, et al. Predictive value of attenuation coefficients measured as Hounsfield units on noncontrast computed tomography during flexible ureteroscopy with holmium laser lithotripsy: a single-center experience. *J Endourol*. 2012;Volume Number 9:Pp. 1125–1130. doi:10.1089/end.2012.0154
11. Molina WR, Marchini GS, Pompeo A, et al. determinants of holmium: yttrium- aluminum-garnet laser time and energy during ureteroscopic laser lithotripsy. *Urology*. 2014;83(4):738–744. doi:10.1016/j.urology.2013.11.017
12. Teichman JMH, George J V, Randolph D G. Holmium:yttrium-aluminum-garnet lithotripsy efficiency varies with stone composition. *Urology*. 1998;52(3):392–397. doi:10.1016/S0090-4295(98)00239-8
13. Athanasios G, Skolarikos A, Buchholz N. Papatsoris. Intracorporeal laser lithotripsy. *Arab Journal of Urology*. 2012;10(3):301–306. doi:10.1016/j.aju.2012.02.006
14. Vassar GJ, Teichman JM, Glickman RD. HOLMIUM: YAG LITHOTRIPSY EFFICIENCY VARIES WITH ENERGY DENSITY. *J Urol*. 1998;160(2):471–476. doi:10.1016/S0022-5347(01)62927-6
15. el-Assmy A, Abou-el-Ghar ME, el-Nahas AR, et al. Multidetector computed tomography: role in determination of urinary stone composition and disintegration with extracorporeal shock wave lithotripsy – an in vitro study. *Urology*. 2011;77(2):286–290. doi:10.1016/j.urology.2010.05.021
16. Budavari S, O'Neil MJ, Smith A, et al. The Merck index: An encyclopedia of chemicals, drugs, and biologicals. 11th ed. Rahway, NJ: Merck and Co. Inc., 1989. 598.
17. Jansen ED, van Leeuwen TG, Motamedi M, et al. Temperature dependence of the absorption coefficient of water for midinfrared laser radiation. *Lasers Surg Med*. 1994;14(3):258–268. doi:10.1002/lsm.1900140308
18. Sea J, Jonat LM, Chew BH, et al. Optimal power settings for Holmium:YAG lithotripsy. *J Urol*. 2012;187(3):914–919. doi:10.1016/j.juro.2011.10.147
19. Teichman JM, Vassar GJ, Glickman RD. Holmium:yttrium aluminum-garnet lithotripsy efficiency varies with stone composition. *Urology*. 1998;52 (3):392–397.

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