AUA **Update Series** 2020
Lesson 5 Volume 39

Dusting vs Extraction Strategies during Ureteroscopy for Renal Calculi *

Learning Objective: At the conclusion of this continuing medical education activity, the participant will be able to select different strategies for ureteroscopic renal stone surgery, determine how laser parameter selection can improve lithotripsy efficiency and identify the important safety considerations to optimize patient outcomes.

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***This AUA Update addresses the Core Curriculum topics of Surgical Energy and Urolithiasis, and the American Board of Urology Module: Calculus, Laparoscopy-Robotics and Upper Tract Obstruction.**

Release date: January 2020

Expiration date: January 2023

Key Words: ureteroscopy; lasers, solid-state; ultrasonic surgical procedures; lithotripsy, laser

EVOLUTION OF FLEXIBLE URETEROSCOPY AND LASER LITHOTRIPSY

In the modern day there has been a notable increase in the use of ureteroscopy, so that it is now the number one surgical modality for treating upper urinary tract stones in North America.[1, 2] The 2 major drivers of this growing trend, at the expense of shock wave lithotripsy, are 1) advances in endoscopic technology, such as flexible ureteroscopes that can safely access all parts of the ureter and kidney with minimal trauma, and 2) the widespread availability of the Ho:YAG laser, which permits lithotripsy in all stone locations regardless of stone composition. Ancillary instrumentation and devices such as laser fibers, retrieval baskets and ureteral access sheaths have become smaller, more flexible and able to withstand greater repeated use, such that URS can be performed for larger kidney stones with relatively minimal morbidity compared to percutaneous renal stone surgery.

Next generation Ho:YAG systems provide the surgeon with a powerful range of laser settings and parameters for breaking up stones. Strategies for treating renal stones with URS consist of dusting, whereby fine fragments are left in situ for spontaneous passage, in contrast to fragmentation and active basket retrieval of fragments. A third method is the hybrid technique, where the stone is initially dusted and when finished larger fragments are actively retrieved. In this Update we provide an overview of the different techniques to consider when performing ureteroscopic renal stone surgery, and how an understanding of laser physics and parameter selection along with safety considerations is important to improve lithotripsy efficiency and optimize patient outcomes.

PHYSICS OF LASER LITHOTRIPSY

Ho:YAG is a solid-state, flashlamp pumped laser that emits pulsed energy at 2100 nm wavelength. Holmium energy is strongly absorbed by water and all urinary stone compositions, and thus is effective and safe for urinary stone comminution.[3,4] Pulse energy (J), the amount of energy in a single pulse, and frequency (Hz), the number of pulses delivered per second, can be selected by the user. **Time averaged laser power (W) can be simply calculated as pulse energy (J) × frequency (Hz)**.

Energy emitted from the tip of the laser vaporizes adjacent fluid, creating a vapor bubble. This bubble serves as a pathway permitting transmission of radiation between the parted fluid, hence the term "Moses effect" is used to describe this phenomenon.[5,6] Laser energy is less attenuated traveling through vapor than fluid so subsequent laser pulses that take advantage of the presence of a vapor bubble can deliver more energy into the stone. **When laser energy is absorbed by stone a photothermal reaction occurs with chemical decomposition of stone material.[7]**

Until recently, holmium laser systems were low power (15 to 20 W) and only capable of ≤15 to 20 Hz pulse frequency. Laser parameters of high pulse energy such as 0.8 to 1.0 J and low frequency such as 8 to 12 Hz (power 6 to 12 W) were typically used to allow a "fragmentation" strategy wherein the laser is placed in direct contact with the stone and sequential subdivision is performed, followed by extraction of the stone fragments.[8, 9] By incorporating multiple rods and flashlamps into new laser systems, it became possible to expand the pulse energy and frequency that could be delivered. These newer high powered (10 to 120 W) holmium laser systems capable of 50 to 80 Hz pulse frequency and low pulse energies such as 0.2 to 0.3 J have dramatically expanded the available settings for laser lithotripsy.[10] **Dusting uses high frequency, low pulse energy settings to break stones into submillimeter fragments.[10-13]** Table 1 provides an overview of the different laser lithotripsy modes and settings, including dusting, popcorning and pop-dusting.[13-16]

From a practical perspective stone ablation volume and fragment size increase proportionally with pulse energy.[17-19] **There are several drawbacks to using higher pulse energy, including greater laser fiber tip degradation and increased stone retropulsion.[18-21]** Retropulsion increases the distance between the laser tip and stone, resulting in less energy reaching the stone.[3] Time is also lost repositioning to regain contact with the stone as it moves. Raising pulse frequency while maintaining pulse energy increases the time averaged power and unsurprisingly elevates the fragmentation rate, which interestingly has a negligible effect on stone retropulsion.[22-24] High powered holmium lasers can now achieve frequencies up to 80 Hz, which can improve efficiency. However, as time averaged power increases, one must remain mindful of bulk thermal effects.

Next generation Ho:YAG systems also provide the option of varying pulse duration. Traditional short pulse modes typically range from 150 to 350 milliseconds, while long pulse modes range from 500 to 1300 milliseconds. While the same amount of energy is transmitted in each pulse, the peak power attained in long pulse mode is lower, resulting in less retropulsion and fiber tip degradation.[25-27] Pulse modulation is also being used for select modes of laser operation. Most commonly this modulation involves sequencing 2 or more pulses closely together so the following pulses can take advantage of the vapor bubble and transmit a greater portion of the pulse energy to the stone. An example is the Moses technology where the energy is delivered over 2 pulses.[28] This platform has a Moses contact mode, intended for operation at a close distance, and a Moses distance mode, designed for lithotripsy at a distance of 1 to 2 mm. Appendix 1 provides a summary of how frequency, pulse energy, pulse duration and pulse modulation affect the laser lithotripsy performance characteristics of fragmentation, retropulsion and fiber burnback.

TECHNIQUES OF URETEROSCOPIC RENAL STONE SURGERY

Laser strategy depends on stone and patient characteristics, available equipment, surgeon experience, and surgeon and patient preference. One can break stones either into smaller fragments that are retrieved with ancillary devices, known as fragmentation and basketing, or into very fine fragments that are left in situ for spontaneous passage, ie dusting. The optimal laser lithotripsy may be to use both strategies selectively, since

ABBREVIATIONS: CT (computerized tomography), Ho:YAG (holmium:yttrium-aluminum-garnet), SFR (stone-free rate), UAS (ureteral access sheaths), URS (ureteroscopy)

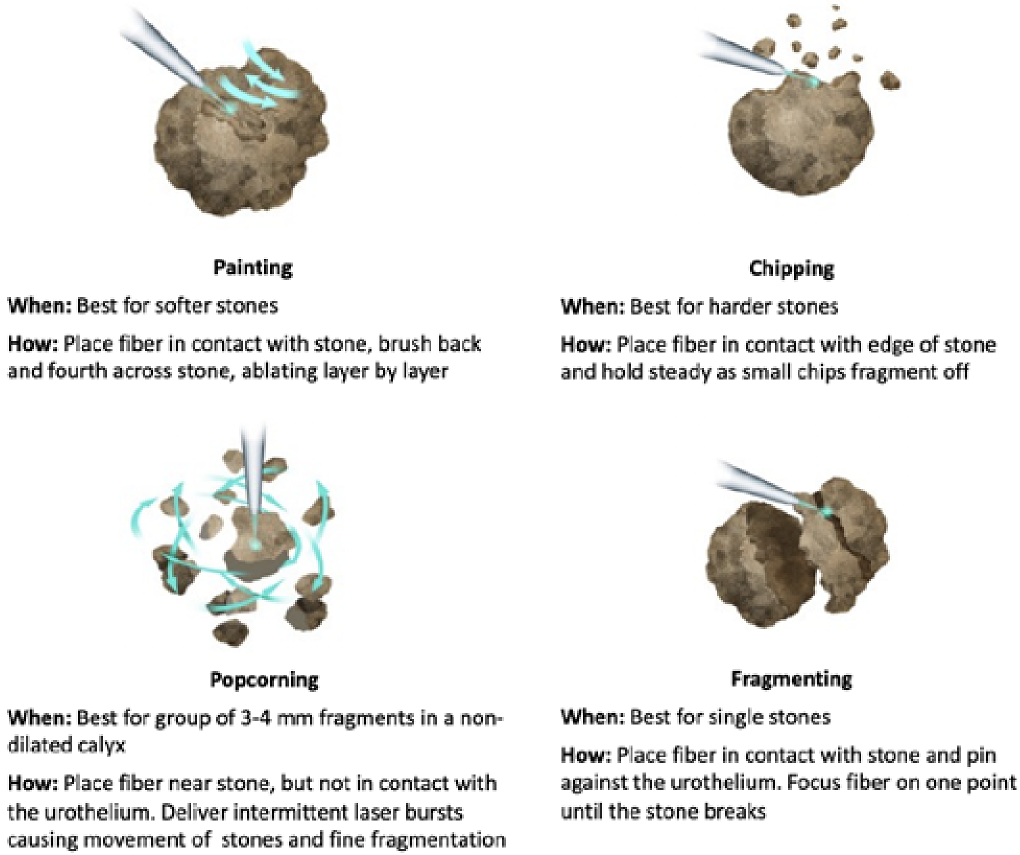

Figure 1. Fragmentation and dusting techniques for laser lithotripsy of renal stones.

dusting is most suited for soft stones and fragmentation and basketing are more useful as the stone hardness increases. Especially for hard stone compositions, a hybrid approach that initially uses dusting followed by retrieval of larger fragments may be necessary. An advantage of dusting, just as in shock wave lithotripsy, is that a stent may not be needed at the end of the procedure, which can have significant implications for postoperative symptoms and quality of life.

Dusting. The aim of this technique is to incorporate a laser setting parameter so that fragments breaking off the stone are as small as possible, thereby maximizing the goal of complete spontaneous passage. When treating renal stones, dusting consists of a contact laser lithotripsy phase and a non-contact laser lithotripsy phase. The first phase is the initial debulking step where the surgeon sculpts the stone, keeping it intact as a single entity and reducing its overall size by ejecting tiny fragments. Eventually, no matter how good the surgeon's skill, the stone will end up breaking into smaller chunks. During the second phase these larger fragments are pulverized with non-contact laser lithotripsy.

Contact Phase Laser Lithotripsy: Painting/dancing and chipping are techniques used during the initial phase of dusting (fig. 1).[29] Painting is accomplished by sweeping the laser fiber tip horizontally across the face of the stone while firing continuously. Dancing is the movement of the fiber going forward and backward so that it does not get stuck on the stone surface due to fragmentation. Ablation of the stone surface should be uniform and to bombard parts of the stone that project forward, taking precaution in the center to avoid fracturing the stone. For hard stones a chipping technique can be used by firing the fiber tip at the outer edge of the stone to break off chips <1 mm.

Dusting is a dynamic process that requires constant movement of the fiber on the stone. The laser setting initially used may need to be modified as the stone is dusted and decreases in size. If the stone begins to "wobble," it means the setting is no longer optimal, and reducing the pulse energy or frequency can improve lithotripsy efficiency (fig. 2).[10] Once the stone breaks into smaller fragments, the next step is to perform non-contact laser lithotripsy so these fragments become even smaller.[29]

Non-Contact Laser Lithotripsy: **Also known as popcorning due to the chaotic and noisy movement of fragments,[14] this technique is executed by activating the fiber tip a few millimeters away from the fragments without making contact.** Using intermittent laser bursts and specific laser settings (table 1),

Table 1. Laser lithotripsy modes and typical settings

Mode	Pulse Energy/Frequency	Laser Settings	Power (W)
Fragmentation	High/low	0.8 J×8 Hz/1.0 J×12 Hz	<15
Dusting	Low/high	0.2-0.4 J×50-80 Hz	15-24
Popcorning	High/moderate	1.0 J×15-20 Hz	15-20
Pop-dusting	Moderate/high	0.5 J×80 Hz	40

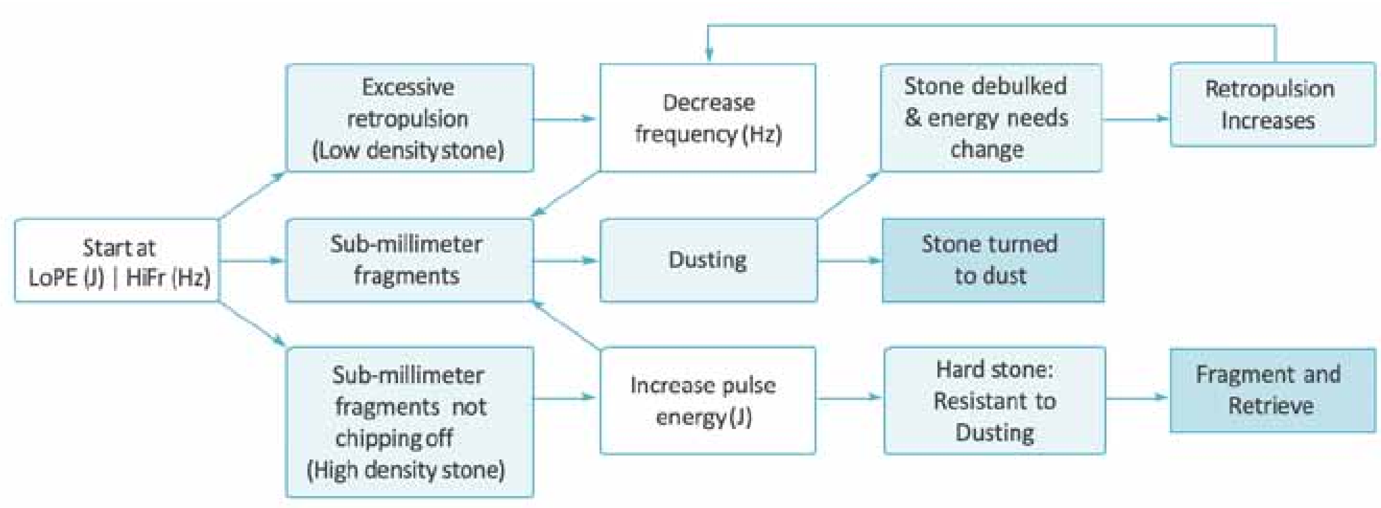

Figure 2. Algorithm for adjusting laser settings when using low pulse energy (*LoPE*), high frequency (*HiFr*) dusting technique for renal stones during ureteroscopy.

this technique results in a whirlpool-like effect and stone disintegration as the fragments move around and come in direct contact with the laser tip (fig. 1). The technique allows the surgeon to avoid spending time repositioning the laser on the stone between pulses. In vitro studies have shown that using higher pulse frequencies/higher power,[15] keeping the laser fiber positioned closer to the stone surface and performing the procedure in a smaller cavity (eg a small calyx is better than the renal pelvis) improve submillimeter fragmentation outcomes.[30] If the stone is too hard and not amenable to dusting or the calyx is too dilated for effective popcorning, it may be more appropriate to retrieve the fragments.

Extraction. The objective of fragmentation is to sequentially subdivide a stone into smaller pieces that are suitable for basket extraction or spontaneous passage. This technique is also applied to very hard stones that are resistant to dusting and chipping strategies. **The laser fiber is positioned on a central portion of the stone with gentle pressure to pin the stone against the wall of the calyx/papilla or additional stone material.** The laser is fired with pulse energy 0.8 to 1.2 J and frequency 6 to 8 Hz, boring into the stone until it cracks.[29] Use of low frequency is important as delivery of laser energy must be stopped immediately once the stone breaks or retropulses to prevent inadvertent advancement and firing of the laser into the tissue behind the stone. With lower frequency, fewer pulses will impact the tissue before the laser pedal is released. Gentle pressure on the stone counteracts retropulsion and ensures laser fiber-stone contact, maximizing energy delivery to the stone. Retropulsion and/or disruptive vibration of the stone still occurs. **Use of long pulse mode on laser systems equipped with options for variable pulse duration selection will also decrease retropulsion and stone movement.**[31, 32]

Determination that stone fragments have been reduced to proper size for extraction can be problematic. Fragments that are too large will not fit through an access sheath or down the ureter, and treatment of fragments beyond removal size is inefficient and will result in more material and more passages through the ureter for retrieval. Commonly used strategies to address this problem include use of the laser fiber as a reference measurement, although inaccuracies with depth perception limit this approach. Future strategies may use imaging algorithms to assist the urologist. Ludwig et al reported on the use of imaging software to provide a digital caliper to facilitate determination of stone fragment size.[33]

Once the stone is fragmented, basket extraction is commonly done to remove the fragments from the body. A variety of basket configurations have been developed but the most commonly used basket type is the 4-wire, tipless variety that allows reliable entrapment of the stone with minimal trauma to the collecting system and ureter. Modern-day baskets for renal work contain nitinol wire instead of steel. **Nitinol is a nickel-titanium alloy with elastic and shape memory properties that make it robust for repeated use.** Some baskets have been developed for unique situations, including enhanced wire patterns to secure smaller fragments, and baskets that engage stones end-on with release mechanisms to prevent the basket and stone from becoming lodged.[34] This basket type is particularly useful when attempting to extract or reposition a stone from the lower pole of the kidney. While not as sturdy as standard 4-wire baskets, these end-engage baskets have enough holding force to extract fragments via an access sheath. Some prefer to extract fragments using these retrieval devices through the ureter, as they are easy to release in case they become stuck in the ureter if the fragments are too large. However, these open-ended baskets do not hold on to the stone as robustly as the wired configurations.

For repetitive passes up and down the ureter to remove multiple fragments UAS are used to reduce trauma to the ureter and facilitate reentry of the ureteroscope into the renal pelvis. A variety of UAS are available, and the most commonly used have inner diameters of 10Fr to 13Fr, sufficient to accommodate available ureteroscopes. The larger UAS allow extraction of larger fragments but can be more difficult to insert and may increase the risk of ureteral injury.[35] In general, when a fragmentation and extraction strategy is chosen and many passes are expected to clear the stone fragments, placement of a ureteral access sheath should be considered. **Keeping the gauge of the ureteral access sheath as low as possible will be safer for the ureter, although the smaller sheaths will limit extraction of larger fragments.** If the ureter is already stented, the dilated ureter may accommodate larger access sheath sizes. Another important consideration is to be aware of the size of the ureteroscope being used before selecting a ureteral access sheath size, as not all ureteroscopes will enter the lumen of the smaller sheaths.[36] The advantages and disadvantages of dusting compared to fragmentation and retrieval are outlined in Appendix 2.

CLINICAL EVIDENCE

Dusting. When examining the performance of one laser technique over another clinical evidence may not be generalizable due to the heterogeneity of patient populations, unpredictable complexity of renal stone surgery and stone hardness, and lack of standardization in equipment, techniques, holmium systems and laser settings used. Important end points to consider when determining efficacy include operative time, ureteral stenting rate, complications, unplanned encounters related to URS, stone-free rate assessment and long-term re-treatment rates. In general, comparative evidence is limited regarding fragmentation/retrieval and dusting techniques for URS, and only 1 randomized controlled trial has compared the 2 approaches for treating ureteral stones. Schatloff et al did not find a significant difference in SFR between the 2 groups, although unplanned visits were higher when ureteral fragments were left in situ for spontaneous passage.[37] A major limitation of the study was that it did not incorporate low pulse energy dusting settings, and so fragments were broken down to 2 mm and not finer fragments <1 mm.

Tracey et al recently reported a retrospective series of dusting technique using high frequency, low pulse energy settings in 71 patients.[10] Pulse energy setting ranged between 0.2 and 0.5 J with frequencies between 50 and 80 Hz. Stone clearance with <2 mm residual fragments was 74% and the zero fragment rate was 62%. The emergency department visit rate after URS was 6% with no patients requiring surgical reintervention. Of 781 patients treated with the dusting technique and x-ray within 3 months 20% required repeat surgery at a median follow-up of 4.2 years.[38] In particular, the risk of repeat surgery was increased in renal units with RFs >2 mm.

A major limitation of most studies is that computerized tomography is rarely used in all patients to determine the SFR. **When CT has been used to assess fragmentation and retrieval techniques zero fragment rates were between 55% and 60%.[39]** For this Update we assessed all studies for renal stone treatment containing a description of an exclusive fragmentation with spontaneous passage technique (ie dusting) or active retrieval that relied on reporting stone clearance using CT in all patients (table 2).[40-43] In the series with a complete SFR of 81% at 6 weeks the residual fragment rate for stones <2 to <3 mm ranged from 84% to 91%.[40] However, in none of these studies were low pulse energy, high frequency techniques used nor were specifications of the Ho:YAG system provided and, therefore, they may not be representative of current technical practice.

Retrieval. CT based outcomes for retrieval techniques when treating kidney stones are listed in table 3.[42, 44-46] Complete SFR was 90% in a small series of 50 patients reported on by Redondo et al[45] compared to 73% in a much larger series of active retrieval in 212 patients reported on by York et al.[46] Recently the EDGE (Endourologic Disease Group for Excellence) research consortium published results of a multi-institutional prospective study comparing fragmentation and retrieval against dusting technique for radiopaque renal stones measuring 5 to 20 mm.[11] RFs on x-ray and/or ultrasound were assessed at 4 to 6 weeks. On bivariate analysis the SFR was higher for the retrieval group (74.7% vs 58.1%) but this difference was not significant on multivariate analysis. The outcomes for stone clearance may be confounded by the dusting group having significantly larger stones. However, operative time was significantly longer for the retrieval group, and there were no differences in symptomatic RFs, complications or reinterven-

Table 2. Summary of studies assessing dusting technique for treating renal stones with follow-up by CT

	Cocuzza et al[40]	Hussain et al[41]	Lee et al[42]	Fayad et al[43]
Study design	Retrospective cohort	Retrospective cohort	Retrospective cohort	Prospective cohort
Study period	2002-2007	2005-2008	2010-2015	2012-2015
No. cases	63	185	76	60*
Mean stone size (mm)	11	12	11	14
% UAS used	33	3	100	100
Laser power setting†	Not specified (1.0 J/10 Hz)	Not specified (0.5 J/10 Hz)	Not specified	Not specified (0.8 J/12 Hz)
Mean operative time (mins)	68‡	Not specified§	82	110
% Stenting used	100	72	100	0
% Overall complications	3	Not specified§	11	8
Residual fragment criteria	Fragments 0	Fragments <2 mm	Fragments <3 mm	Fragments <3 mm
Timing of CT	6 Wks	Within 6 mos	4 Wks	12 Wks
% Stone clearance rate	81	91	87	84

*Lower calyceal stones.
†Lowest pulse energy (J)/highest pulse frequency (Hz).
‡Includes multiple procedures.
§Operative time and complications were not assessed.

Table 3. Summary of studies assessing fragmentation and active retrieval technique for renal stones with follow-up by CT

	Somani et al[44]	Redondo et al[45]	Lee et al[42]	York et al[46]
Study design	Prospective cohort	Prospective cohort	Retrospective cohort	Retrospective cohort
Study period	2007-2011	2012-2013	2010-2015	2013-2016
No. cases	Fiberoptic flexible URS—59, digital flexible URS—59	50	172	214
Mean stone size (mm)	Fiberoptic flexible URS—12.8, digital flexible URS—12.0	<20, 21-30, >30	11.1	6.2
% UAS used	100	100	100	94*
Laser power setting†	Not specified	20-30 W (0.5 J/15 Hz)	Not specified	Not specified
Mean operative time (mins)	Fiberoptic flexible URS—53.8, digital flexible URS—44.5	96.6	82.5	54
% Stenting used	Not specified	100	100	Not specified
% Overall complications	1	8	10	Not specified
Residual fragment criteria	Fragments <2 mm	Fragments 0	Fragments <3 mm	Fragments 0
CT timing	1 Mo	3 Mos	4 Wks	3 Mos
% Stone clearance rate	Fiberoptic flexible URS—86, digital flexible URS—88	90	89	73

*Basket retrieval without a sheath was performed in 6% of cases.
†Lowest pulse energy (J)/highest pulse frequency (Hz).

tion rates. Humphreys et al concluded that retrieval results in a higher SFR at the expense of longer procedure time and greater use of UAS (100% vs 16% for dusting) may increase total procedural cost.[11]

The limited data comparing dusting and basketing techniques do not allow us to determine which method is superior. Each approach has advantages and disadvantages, and the modern-day stone surgeon should be familiar with both techniques. In select cases dusting offers the option of stentless URS, while retrieval with a ureteral access sheath often necessitates a ureteral stent. **The decision regarding which strategy to use should be based on the clinical scenario and available resources.**[47] A combination of both techniques may be needed to optimize outcomes, cost, time and morbidity. Regardless of technique, studies have indicated that complete SFRs after URS for renal stones are suboptimal,[48] and future directions may focus on suction or stabilization devices that can optimize laser strategies.

OTHER POTENTIAL BENEFITS

Stone dusting has been shown to be faster than fragmentation and retrieval. A contributing factor as to why fragmentation and retrieval are slower is the need for a skilled assistant to operate the basket (position and open/close slider). This necessity may be less of a problem in the future with development of accessory devices for disposable ureteroscopes that allow the surgeon to open and close a basket with a trigger mechanism, optimizing these additional controls for the primary operator. However, even with this type of device, dusting is less cumbersome than extensive basket extraction when the surgeon is operating alone, as commonly occurs in community practice and even increasingly at large tertiary medical centers. Extraction is preferable when a premium is placed on removal of all stone fragments, as it is for commercial airline pilots. Similarly with infected stones or patients at high risk for infectious complications, such as those with spinal cord injury, minimizing manipulation and more complete extraction of stone material may produce better outcomes and decrease infectious postoperative complications.

FUTURE DIRECTIONS

New lithotripsy modes are effective adjuncts to fragmentation laser lithotripsy and have been observed to shorten operative time.[11] **However, the higher powers used with these modes present a risk of overheating the calyceal fluid as demonstrated in in vitro and in vivo studies.**[49-53] Temperatures in 1 study reached 60C after 10 seconds of laser activation at 40 W power settings.[49] Even short (<1 second) exposure to this temperature produces cell death and tissue injury, which can lead to renal scarring, obstruction of the ureter or collecting system and loss of renal function.[54-56] A follow-up in vivo porcine study confirmed that lethal temperatures are generated during laser lithotripsy within a renal calyx, resulting in grossly apparent pathological thermal injury.[57] Results from in vitro and in vivo experiments were supported by computer simulations of the heating produced in these scenarios.[58] Taken together, these data raise concerns that toxic heating of urological tissues could be produced by laser settings used in current clinical practice. Hence, there is a need to map the thermal safety boundaries and create parameter guidelines for high powered laser lithotripsy.

Surprisingly, assessment of thermal safety in laser lithotripsy has lagged behind the clinical introduction of new high powered laser systems, which do not have automated safety features or real-time sensing of intrarenal temperature. Additionally there is no guidance from industry, professional groups or regulatory bodies on selection of safe laser settings. **While bench studies suggest that increasing irrigation rate can partly control temperature elevation,[49-53] this can only be achieved in certain scenarios, since intrarenal pressures must not exceed 40 cm H_2O in order to minimize risk of infection, sepsis and hemorrhagic complications from pyelovenous and pyelosinus backflow.[59-61]** As the range of laser settings continues to expand, laser power and irrigation rate must be considered together to establish safe operating parameters.

Appendix 1. Relationship among pulse energy, frequency, pulse duration and pulse modulation on laser lithotripsy performance

	Pulse Energy (J)		Frequency (Hz)		Pulse Duration		Pulse Modulation
	High	Low	High	Low	Short	Long	Moses Technology
Fragmentation	↑	↓	↑	↓	No effect	No effect	↑
Retropulsion	↑	↓	=/↑	No effect	↑	↓	↓
Burnback	↑	↓	↑*	No effect	↑	↓	↓

*Increase in burnback only if total power increases.

Appendix 2. Advantages and disadvantages of dusting and retrieval techniques for ureteroscopic laser lithotripsy

Method	Advantages	Disadvantages
Dusting	Produces smaller fragments, avoids routine use of ureteral access sheath and thus reduces risk of ureteral trauma, shorter operation time, no need for assistant, avoids routine postoperative stenting in select cases, able to offer treatment in cases of failed ureteral access sheath insertion	Often requires next generation laser systems (high capital equipment cost), may not be suitable for hard stones (eg calcium oxalate monohydrate), stone-free rate may depend on the surgeon's skill, concern for fragment drainage in certain patients (eg spinal cord injury), may result with no fragment for analysis unless basket used at end for fragment extraction
Fragmentation and basket retrieval	Can use low power laser system (low capital equipment cost), ability to extract complete stone in non-complicated cases, suitable for hard stones, able to send fragments for composition analysis	Produces larger fragments, longer operation time, higher disposable costs, need for assistant, risk of ureteral injury from using ureteral access sheath, routine ureteral stenting if using access sheath

REFERENCES

1. Ordon M, Urbach D, Mamdani M et al: The surgical management of kidney stone disease: a population based time series analysis. J Urol 2014; **192:** 1450.
2. Oberlin DT, Flum AS, Bachrach L et al: Contemporary surgical trends in the management of upper tract calculi. J Urol 2015; **193:** 880.
3. 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:** 258.
4. Teichman JMH, Vassar GJ and Glickman RD: Holmium:yttrium-aluminum-garnet lithotripsy efficiency varies with stone composition. Urology 1998; **52:** 392.
5. Isner JM, DeJesus SR, Clarke RH et al: Mechanism of laser ablation in an absorbing fluid field. Lasers Surg Med 1988; **8:** 543.
6. Isner JM and Clarke RH: Cardiovascular Laser Therapy. New York: Raven Press 1989.
7. Chan KF, Vassar GJ, Pfefer TJ et al: Holmium:YAG laser lithotripsy: a dominant photothermal ablative mechanism with chemical decomposition of urinary calculi. Lasers Surg Med 1999; **25:** 22.
8. Chan KF, Pfefer TJ, Teichman JM et al: A perspective on laser lithotripsy: the fragmentation processes. J Endourol 2001; **15:** 257.
9. Bader MJ, Pongratz T, Khoder W et al: Impact of pulse duration on Ho:YAG laser lithotripsy: fragmentation and dusting performance. World J Urol 2015; **33:** 471.
10. Tracey J, Gagin G, Morhardt D et al: Ureteroscopic high-frequency dusting utilizing a 120-W holmium laser. J Endourol 2018; **32:** 290.
11. Humphreys MR, Shah OD, Monga M et al: Dusting versus basketing during ureteroscopy—which technique is more efficacious? A prospective multi-center trial from the EDGE Research Consortium. J Urol 2018; **199:** 1272.
12. Santiago JE, Hollander AB, Soni SD et al: To dust or not to dust: a systematic review of ureteroscopic laser lithotripsy techniques. Curr Urol Rep 2017; **18:** 32.
13. Aldoukhi AH, Roberts WW, Hall TL et al: Holmium laser lithotripsy in the new stone age: dust or bust? Front Surg 2017; **4:** 57.
14. Chawla SN, Chang MF, Chang A et al: Effectiveness of high-frequency holmium:YAG laser stone fragmentation: the "popcorn effect." J Endourol 2008; **22:** 645.
15. Emiliani E, Talso M, Cho SY et al: Optimal settings for the noncontact holmium:YAG stone fragmentation popcorn technique. J Urol 2017; **198:** 702.
16. Pietropaolo A, Jones P, Whitehurst L et al: Role of 'dusting and pop-dusting' using a high-powered (100 W) laser

machine in the treatment of large stones (≥15 mm): prospective outcomes over 16 months. Urolithiasis 2019; **47:** 391.
17. Shin RH, Lautz JM, Cabrera FJ et al: Evaluation of novel ball-tip holmium laser fiber: impact on ureteroscope performance and fragmentation efficiency. J Endourol 2016; **30:** 189.
18. Sea J, Jonat LM, Chew BH et al: Optimal power settings for Holmium:YAG lithotripsy. J Urol 2012; **187:** 914.
19. Kronenberg P and Traxer O: In vitro fragmentation efficiency of holmium: yttrium-aluminum-garnet (YAG) laser lithotripsy—a comprehensive study encompassing different frequencies, pulse energies, total power levels and laser fibre diameters. BJU Int 2014; **114:** 261.
20. Mues AC, Teichman JMH and Knudsen BE: Quantification of holmium:yttrium aluminum garnet optical tip degradation. J Endourol 2009; **23:** 1425.
21. Lee H, Ryan RT, Teichman JM et al: Stone retropulsion during holmium:YAG lithotripsy. J Urol 2003; **169:** 881.
22. Spore SS, Teichman JM, Corbin NS et al: Holmium:YAG lithotripsy: optimal power settings. J Endourol 1999; **13:** 559.
23. Li R, Ruckle D, Keheila M et al: High-frequency dusting versus conventional holmium laser lithotripsy for intrarenal and ureteral calculi. J Endourol 2017; **31:** 272.
24. White MD, Moran ME, Calvano CJ et al: Evaluation of retropulsion caused by holmium:YAG laser with various power settings and fibers. J Endourol 1998; **12:** 183.
25. Kamal W, Kallidonis P, Koukiou G et al: Stone retropulsion with Ho:YAG and Tm:YAG lasers: a clinical practice-oriented experimental study. J Endourol 2016; **30:** 1145.
26. Sroka R, Pongratz T, Scheib G et al: Impact of pulse duration on Ho:YAG laser lithotripsy: treatment aspects on the single-pulse level. World J Urol 2015; **33:** 479.
27. Kang HW, Lee H, Teichman JM et al: Dependence of calculus retropulsion on pulse duration during Ho:YAG laser lithotripsy. Lasers Surg Med 2006; **38:** 762.
28. Elhilali MM, Badaan S, Ibrahim A et al: Use of the Moses technology to improve holmium laser lithotripsy outcomes: a preclinical study. J Endourol 2017; **31:** 598.
29. Hecht SL and Wolf JS Jr: Techniques for holmium laser lithotripsy of intrarenal calculi. Urology 2013; **81:** 442.
30. Aldoukhi AH, Roberts WW, Hall TL et al: Understanding the popcorn effect during holmium laser lithotripsy for dusting. Urology 2018; **122:** 52.
31. Kalra P, Le N and Bagley D: Effect of pulse width on object movement in vitro using holmium:YAG laser. J Endourol 2007; **21:** 228.
32. Eisel M, Strobl S, Pongratz T et al: In vitro investigations of propulsion during laser lithotripsy using video tracking. Lasers Surg Med 2018; **50:** 333.
33. Ludwig WW, Lim S, Stoianovici D et al: Endoscopic stone measurement during ureteroscopy. J Endourol 2018; **32:** 34.
34. Bechis SK, Abbott JE and Sur RL: In vitro head-to-head comparison of the durability, versatility and efficacy of the NGage and novel Dakota stone retrieval baskets. Transl Androl Urol 2017; **6:** 1144.
35. Traxer O and Thomas A: Prospective evaluation and classification of ureteral wall injuries resulting from insertion of a ureteral access sheath during retrograde intrarenal surgery. J Urol 2013; **189:** 580.
36. Sener TE, Cloutier J, Villa L et al: Can we provide low intrarenal pressures with good irrigation flow by decreasing the size of ureteral access sheaths? J Endourol 2016; **30:** 49.
37. Schatloff O, Lindner U, Ramon J et al: Randomized trial of stone fragment active retrieval versus spontaneous passage during holmium laser lithotripsy for ureteral stones. J Urol 2010; **183:** 1031.
38. Iremashvili V, Li S, Penniston KL et al: Role of residual fragments on the risk of repeat surgery after flexible ureteroscopy and laser lithotripsy: single center study. J Urol 2019; **201:** 358.
39. Ghani KR and Wolf JS Jr: What is the stone-free rate following flexible ureteroscopy for kidney stones? Nat Rev Urol 2015; **12:** 281.
40. Cocuzza M, Colombo JR Jr, Ganpule A et al: Combined retrograde flexible ureteroscopic lithotripsy with holmium YAG laser for renal calculi associated with ipsilateral ureteral stones. J Endourol 2009; **23:** 253.
41. Hussain M, Acher P, Penev B et al: Redefining the limits of flexible ureterorenoscopy. J Endourol 2011; **25:** 45.
42. Lee YJ, Bak DJ, Chung JW et al: Is it necessary to actively remove stone fragments during retrograde intrarenal surgery? Investig Clin Urol 2016; **57:** 274.
43. Fayad AS, Elsheikh MG and Ghoneima W: Tubeless mini-percutaneous nephrolithotomy versus retrograde intrarenal surgery for lower calyceal stones of 2 cm: a prospective randomised controlled study. Arab J Urol 2017; **15:** 36.
44. Somani BK, Al-Qahtani SM, de Medina SD et al: Outcomes of flexible ureterorenoscopy and laser fragmentation for renal stones: comparison between digital and conventional ureteroscope. Urology 2013; **82:** 1017.
45. Redondo C, Ramon de Fata F, Gimbernat H et al: Retrograde intrarenal surgery with holmium-YAG laser lithotripsy in the primary treatment of renal lithiasis. Actas Urol Esp 2015; **39:** 320.
46. York NE, Zheng M, Elmansy HM et al: Stone-free outcomes of flexible ureteroscopy for renal calculi utilizing computed tomography imaging. Urology 2019; **124:** 52.
47. Weiss B and Shah O: Evaluation of dusting versus basketing—can new technologies improve stone-free rates? Nat Rev Urol 2016; **13:** 726.
48. Pearle MS: Is ureteroscopy as good as we think? J Urol 2016; **195:** 823.
49. Aldoukhi AH, Ghani KR, Hall TL et al: Thermal response to high-power holmium laser lithotripsy. J Endourol 2017; **31:** 1308.
50. Wollin DA, Carlos EC, Tom WR et al: Effect of laser settings and irrigation rates on ureteral temperature during holmium laser lithotripsy, an in vitro model. J Endourol 2018; **32:** 59.
51. Buttice S, Sener TE, Proietti S et al: Temperature changes inside the kidney: what happens during holmium:yttrium-aluminum-garnet laser usage? J Endourol 2016; **30:** 574.
52. Molina WR, Silva IN, DaSilva RD et al: Influence of saline on temperature profile of laser activation. J Endourol 2015; **29:** 235.
53. Sourial MW, Ebel J, Francois N et al: Holmium-YAG laser: impact of pulse energy and frequency on local fluid temperature in an in-vitro obstructed kidney calyx model. J Biomed Opt 2018; **23:** 1.

54. Corwin TS, Lindberg G, Traxer O et al: Laparoscopic radiofrequency thermal ablation of renal tissue with and without hilar occlusion. J Urol 2001; **166:** 281.
55. Park BK and Kim CK: Complications of image-guided radiofrequency ablation of renal cell carcinoma: causes, imaging features and prevention methods. Eur Radiol 2009; **19**: 2180.
56. Venkatesan AM, Wood BJ and Gervais DA: Percutaneous ablation in the kidney. Radiology 2011; **261**: 375.
57. Aldoukhi AH, Hall TL, Ghani KR et al: Caliceal fluid temperature during high-power holmium laser lithotripsy in an in vivo porcine model. J Endourol 2018; **32**: 724.
58. Maxwell AD, MacConaghy B, Harper JD et al: Simulation of laser lithotripsy-induced heating in the urinary tract. J Endourol 2019; **33:** 113.
59. Rehman J, Monga M, Landman J et al: Characterization of intrapelvic pressure during ureteropyeloscopy with ureteral access sheaths. Urology 2003; **61:** 713.
60. Auge BK, Pietrow PK, Lallas CD et al: Ureteral access sheath provides protection against elevated renal pressures during routine flexible ureteroscopic stone manipulation. J Endourol 2004; **18:** 33.
61. Jung H, Norby B, Frimodt-Moller PC et al: Endoluminal isoproterenol irrigation decreases renal pelvic pressure during flexible ureterorenoscopy: a clinical randomized, controlled study. Eur Urol 2008; **54:** 1404.

Study Questions Volume 39 Lesson 5

1. The mechanism by which the Ho:YAG laser results in stone disintegration is
   a. cavitation
   b. cavitation followed by a photothermal reaction
   c. photothermal reaction followed by cavitation
   d. photothermal reaction with chemical decomposition of stone material

2. Selection of long pulse duration of 500 to 1,300 μs when fragmenting stones leads to
   a. decreased stone retropulsion
   b. increased stone fragmentation
   c. increased fiber tip degradation
   d. increased risk of scope damage

3. During Ho:YAG laser lithotripsy of a 1.0 cm renal pelvic stone with settings of 0.2 J and 50 Hz, there is minimal change to the stone. The next step is
   a. increase J to 0.3
   b. increase Hz to 60
   c. increase J to 0.4 and increase Hz to 80
   d. reposition the stone into an upper pole calyx

4. Ureteral access sheaths facilitate basket extraction of stones from the kidney but can increase the risk of
   a. raised intrarenal pressure
   b. ureteral injury
   c. infection
   d. ureteroscope breakage

5. During ureteroscopic laser lithotripsy, intrarenal pressures should not exceed 40 cm H_2O in order to minimize risks of
   a. renal scarring
   b. ureteral obstruction
   c. infection and sepsis
   d. subsequent renal insufficiency

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