Lithotripsy: Choose Your Laser

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FOR THE PAST two decades, lithotripsy strategies for the treatment of nephrolithiasis have been dominated by the development and optimisation of holmium lasers. Holmium lasers have become the gold standard in interventional management of renal stones as the safest, most versatile, and most effective approach. However, alternatives for stone ablation are now emerging, including thulium lasers as a direct competitor to holmium lasers, and ballistic or pneumatic devices offering alternative ablation strategies. At the 35th Annual European Association of Urology (EAU) Congress, expert presenters discussed these alternatives for lithotripsy on Sunday, 19th July 2020 in a plenary session, titled 'Stones: The Role of Innovation'.

HOLMIUM LASERS

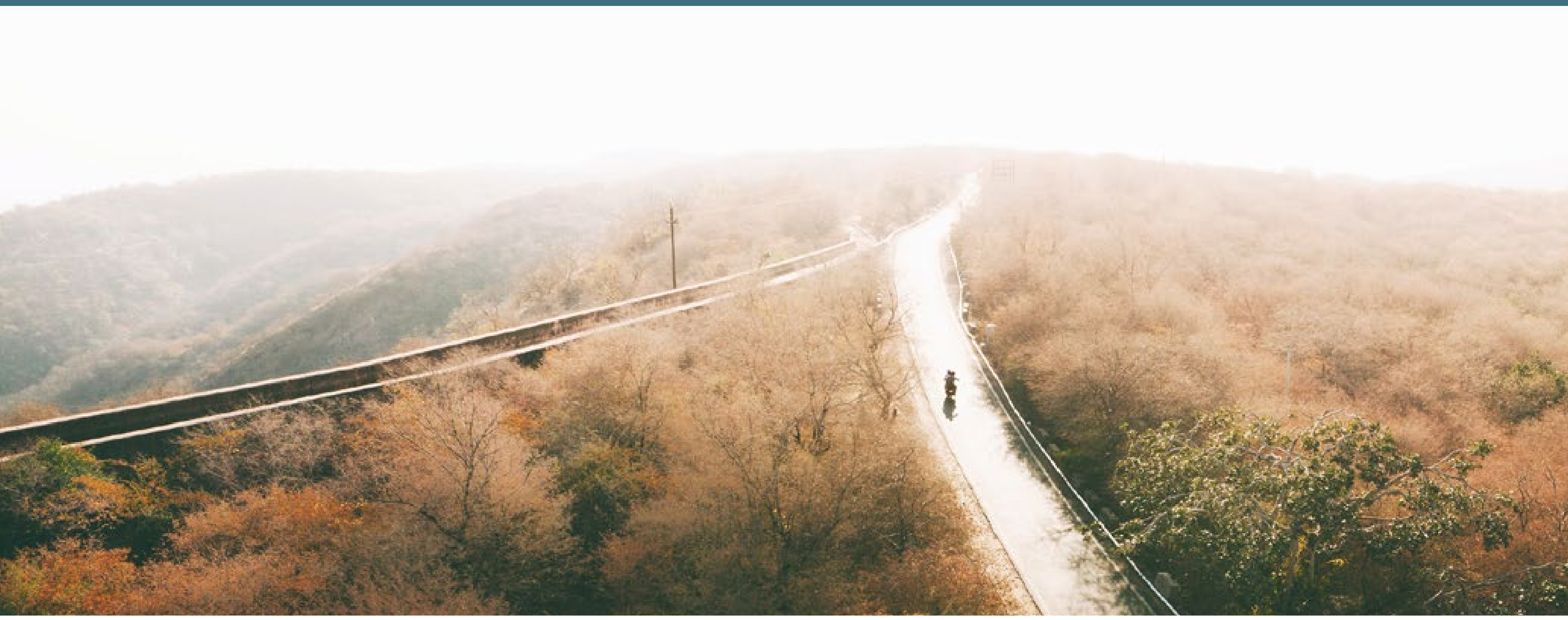
In his presentation, Dr Khurshid Ghani, Ann Arbor, Michigan, USA, outlined the mechanism of ablation performed by holmium lasers, described factors impacting their efficacy in lithotripsy, and highlighted recent advancements improving their use in clinical practice.

Current Practice

Holmium lasers predominantly use a photothermal ablation mechanism to fragment renal stones, maximising energy transfer to the stone by laser contact. A photoacoustic effect causes additional fragmenting of the stones, but this effect is minimal and mainly plays a role in the 'popcorning' or 'pop-dusting' approaches to laser lithotripsy. Three factors affect successful fragmentation by photothermal ablation with holmium lasers: pulse duration, stone absorption and fragmentation, and fluid absorption. Modern development of holmium lasers has favoured longer pulse duration for finer fragmentation and dusting; however, the risk for collateral and thermal damage from longer pulse durations needs to be considered. The level of stone absorption of laser energy has a maximum threshold, beyond which less fragmentation occurs. Finally, holmium is not well-absorbed by fluid, so it operates best when in direct contact with renal stones. Optimising these three factors has been the focus of the advances in holmium laser systems over the past two decades.

Advances in Holmium Lasers

Next-generation holmium laser systems deliver higher energies and allow surgeons to use higher frequencies for a dusting technique. A significant advance in holmium laser systems was the development of MOSES™ technology (Lumenis, San Jose, California, USA), which delivers a short, low-energy pulse to create a vapour bubble before delivering the actual ablative energy pulse. By manipulating the wave form over two pulses, MOSES 'distance mode' improves fragmentation by 28% when in contact with renal stones, and by 100% when at 1 mm distance from the stone, compared with short pulses of holmium laser.[1] This provides a clinical benefit in improving dusting techniques, as a study of dusting techniques determined that only 23% of dusting occurs when within 0.5 mm of the stone;[1] therefore, for effective dusting, advancements



in laser systems should be optimised to work at distance and not only in direct contact.

Pulse modulation has also been developed for holmium lasers and this was shown to deliver better quality dusting. This results in finer fragments for clearer vision during the procedure, and is valuable for effective clearance and suction techniques, both in current practice and in development. Pulse modulation also results in less retropulsion for easier utility of the laser device.

Multipulse sequencing has improved the quality and speed of fragmentation, with better results than long-pulse techniques. Future holmium laser technologies aim to optimise this effect, with the development of 'pulse trains' of rapidly repeated, similar-energy pulses that aim to avoid the risks of prolonged energy durations without sacrificing the efficacy of high power.

THULIUM LASERS

Thulium lasers represent the leading competitor to holmium lasers for laser lithotripsy, with an emergence of studies in recent years supporting their efficacy and comparing their clinical utility to their holmium laser predecessors. During his presentation, Dr Peter Kronenberg, Amadora, Portugal, highlighted studies comparing both practical and clinical considerations, to determine the scope for thulium lasers to join the field for the interventional management of renal stones.

Practical Comparison

The holmium laser apparatus utilises a resonance chamber for energy amplification, and requires a large cooling mechanism, thus resulting in bulky machinery, weighing up to 300 kg. The thulium laser amplifies within the fibre itself so it does not require a resonance chamber, and can be cooled with a simple fan; this results in an apparatus that is much smaller and lighter, weighing 35–40 kg, 7–9 times lighter, and 8 times smaller than the holmium machine. The holmium laser also requires high power to operate, needing a specialised 46 amps power outlet and consuming 10,000 W of energy. By comparison, the thulium laser can run off a standard power outlet as it consumes only 800 W of energy, which allows for more practical incorporation into pre-existing operating theatre infrastructure.

Clinical Comparison

In comparing the clinical results of the two lasers, it is evident that the fragmentation capability of the thulium fibre laser is faster than that of the holmium laser; the thulium laser fragments stones twice as fast as the holmium laser and completes dusting up to four times as fast.[2,3] Study results found that the thulium laser had faster ablation on every setting and for all stone types.[4] The thulium fibre laser was also found to produce a higher quantity of smaller dusting particles during ablation, which contributes to clearer field of view and ease of suction clearance.

During operation, the thulium fibre laser generates less retropulsion than the holmium laser. As explained by Dr Kronenberg: "Reduced retropulsion makes the thulium fibre much easier to handle, without the need to constantly reposition the fibre tip in relation to its target." The settings available for use with the thulium laser exceed that of the holmium laser, in energy,

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frequency, and pulse duration. Much lower energies are available with the thulium laser (0.025–6.00 J versus 0.200–6.00 J with the holmium laser), allowing for precision dusting. The maximum frequency of the thulium laser reaches 2,400 Hz compared with the holmium laser maximum of 100 Hz, and the pulse duration available extends up to 40 times longer (200–50,000 µsec versus 150–1,300 µsec with the holmium laser). These available settings may offer improved dusting performance in lithotripsy, however, further research analysis and clinical experience is needed to assess the safety profile and real-world impact on intervention for renal stones compared with the well-established holmium laser.

THERMAL INJURY

Recent research has highlighted the impact of collateral thermal injury from the use of lasers in renal stone ablation. In his presentation, Dr Evangelos Liatsikos, Patras, Greece, outlined findings clarifying the risks associated with both holmium and thulium laser systems in lithotripsy. Higher energy, while contributing to speed and efficacy of ablation, generates higher heat, particularly in the presence of low irrigation. The threshold for cellular injury is 43 °C; this threshold is reached within the first 1 second of laser use and returns to normal temperature levels over 5 seconds following laser cessation. Dr Liatsikos highlighted the surgical circumstances associated with greatest risk of thermal injury: low irrigation (passive or gravity irrigation), higher laser energies, and instrument use without an access sheath. For clinical safety, he reported that research analysis recommended that irrigation should be >100 mL/min for powers >30 W and that laser power >100 W cannot be recommended.

Using an access sheath increases irrigation inflow by 35–80% compared to flexible scope alone;[5] therefore, use of an access sheath is recommended to reduce risk of cellular injury. However, increased irrigation poses risk of injury via raised intrarenal pressure, including risk of renal extravasation, haematoma, urinoma, sepsis, postoperative pain, and long-term risk of renal scarring. To reduce the risk of these significant complications, pressure must be maintained <30 mmHg. Use of an access sheath (with a diameter ≥10/12 Fr) increases irrigation but lowers intrarenal pressure, compared to forced irrigation in the absence of an access sheath,[5] helping to reduce the risk of these complications. Newer irrigation tools and surgical technologies in development appreciate the importance of continuous monitoring of both temperature and pressure and are incorporating sensors into their designs.

WHAT'S THE VERDICT?

Holmium lasers balance stone and water energy absorption to be safe and effective for fragmentation of renal stones, when in both direct contact and at distance. Thulium pulse lasers show excellent promise for more efficient renal stone ablation and have practical improvements over bulky holmium lasers; however, the thulium alternative does not have the foundation of evidence and experience that the holmium laser systems have established over the past two decades. Both laser systems present risks of thermal injury that have been historically underappreciated but are important, immediate clinical considerations and are influencing the technological advancements of the lithotripsy systems in development.

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