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Lasers for the treatment of urinary stone disease

Surgery for treating urinary stone disease without lasers has become unimaginable. With the introduction of lasers and flexible ureteroscopes, urinary stones, which were untreatable or challenging to treat in the past, have been easier to treat, resulting in changes in the treatment pattern for urinary stone disease over the past 30 years. In this article, I would like to discuss the past, present, and future of lasers, which are essential for endourologists.

The active medium in a laser is an important factor in determining the wavelength and frequency of light. Gases, such as nitrogen, carbon dioxide (CO_2), helium, and neon, have been used in early lasers as active media. In 1964, neodymium-doped yttrium aluminum garnet (Nd:YAG) was first introduced as a solid medium. Subsequently, various types of solid media have been introduced. Laser lithotripsy using pulsed dye as a medium was first reported in 1987. In urology, many types of lasers, such as Nd:YAG, holmium:YAG (Ho:YAG), thulium:YAG (Thu:YAG), CO_2, potassium titanyl phosphate, lithium triborate, and diode lasers. The advancement of technology and the development of surgical techniques over the last 30 years has made laser lithotripsy one of the effective methods for treating kidney stone disease [1].

Most early lasers are not suitable for treating urinary stones because they emit energy in a continuous mode and generate severe heat that can cause tissue damage. Contrary to continuous lasers, pulsed lasers such as Ho:YAG emit energy in pulses, which produces a photothermal effect, causing stone vaporization. In addition, during stone fragmentation, the retropulsion effect is minimal, which is one of the major advantages. Therefore, Ho:YAG lasers have become one of the most popular laser lithotripters in the last 30 years [2].

Pulse energy and frequency are the most important factors in determining the amount of energy during lithotripsy with a laser. The range of pulse energy and frequency was limited in early Ho:YAG lasers capable of producing low power (20 W). With an early Ho:YAG laser, stone fragmentation was restricted by setting a lower frequency and high pulse energy. As the higher power (100 W) Ho:YAG laser was developed, urologists could perform lithotripsy using a lower pulse energy and higher frequency. With the second-generation Ho:YAG laser, the "dusting" technique was developed, which is defined as laser lithotripsy using a higher frequency (>50 Hz) and lower pulse energy (<0.5 J) [3].

First- and second-generation lasers were operated at a fixed pulse width. However, urologists can determine either short- or long-pulse width modes. For stone surgery, the long-pulse mode has many advantages such as less stone retropulsion and laser fiber tip degradation [4]. The most recent Ho:YAG laser with a power of 120 W can implement the "Moses" technology. The "Moses" technology mode produces two different laser pulses. The first pulse divides the water between the laser fiber and the stone, and the second pulse hits the stone. This technique lowers operative time, thereby reducing stone retropulsion and facilitating better ablation [5].

Ho:YAG laser is still the most widely used laser system for treating urinary stone disease and is recognized as the gold standard in lasers. However, the Ho:YAG laser has several limitations. Compared with pneumatic or ultrasonic lithotripters, excessive dust is formed while disintegrating stones, especially when performing the dusting technique. Excessive heat production is another limitation; therefore, a large generator size is necessary for cooling the laser machine. This generator causes excessive noise, which is also a disadvantage of the Ho:YAG laser. Another problem is the difficulty in producing smaller laser fibers. For these reasons, some urologists have tried to find other types of lasers that can overcome the limitations of the Ho:YAG laser [6].

Thulium fiber lasers (TFLs) are different from solid-state lasers such as Ho:YAG or Thu:YAG lasers. A TFL utilizes thulium-doped fiber as a gain medium instead of an ion-doped YAG crystal. TFL generates less heat than the Ho:YAG laser; therefore, a large water-cooling system is not necessary for TFLs. The fan for cooling a TFL weighs only 36 kg [6]. In addition, the gain medium in a TFL is thin; hence, a smaller laser fiber can be employed. TFLs work at wavelengths that optimize absorption in water, increases the vaporization of stones, increases energy efficiency, and potentially improves laser safety. Previous studies have shown that a TFL not only uses fibers smaller than that in Ho:YAG lasers but also performs stone ablation efficiently [7].

There have been many changes in the treatment of urinary stones due to the development and progress of lasers in the last 30 years. In the treatment of urinary stones, lasers are expected to make many changes and improvements in the future. Endourologists should have a constant interest in lasers.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

AUTHORS' CONTRIBUTIONS

Research conception and design: Sang Hyub Lee and Seung Hyun Jeon. Data acquisition: Sang Hyub Lee. Drafting of the manuscript: Sang Hyub Lee. Critical revision of the manuscript: Sang Hyub Lee and Seung Hyun Jeon. Administrative, technical, or material support: Seung Hyun Jeon. Supervision: Seung Hyun Jeon. Approval of the final manuscript: Sang Hyub Lee and Seung Hyun Jeon.

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