Changing Paradigms in the Treatment of Uroliths by Lithotripsy

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In 1908, Drs. George Muller and Alexander Glass made the following statements about uroliths in dogs: "When the stone is present and causing retention of urine, there is nothing left but to remove the stones by means of an operation called urethrotomy if the stone is lodged in the urethra at the posterior end of the bones of the penis or cystotomy if the stone is located in the bladder."[1] One hundred years later, surgery remains a common procedure for rapid removal of uroliths from the lower urinary tract of dogs. Incorporation of intracorporeal laser lithotripsy and extracorporeal shock wave lithotripsy (ESWL) has provided impetus for a paradigm shift in the way veterinarians manage urinary stones, however. These minimally invasive techniques provide a successful alternative to surgical urolith extraction.

The term lithotripsy is derived from the Greek words "lith" meaning stone, and "tripsis" meaning to crush. A lithotriptor is a device for crushing or disintegrating uroliths. ESWL may be used to fragment and remove uroliths from the upper urinary tract, whereas intracorporeal laser lithotripsy may be used to fragment uroliths in the lower urinary tract by urethrocystoscopy.

INTRACORPOREAL LITHOTRIPSY

Successful medical application of intracorporeal lithotripsy depended on two technological advances: (1) delivery of energy capable of fragmenting uroliths without damaging adjacent tissue, and (2) cystoscopes capable of entering the narrow urethral

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lumen to visualize and manipulate uroliths and their fragments. These technologies allow uroliths to be fragmented in the urinary bladder and urethra. Urolith fragments are retrieved with a stone basket or evacuated by voiding urohydropropulsion. Urolith removal is performed cystoscopically, obviating the need for a surgical incision.

Although several forms of energy (ultrasonic, ballistic, electrohydraulic, and laser) can fragment urinary stones, not all energy forms are suitable for use in companion animals. For example, the probes for ultrasonic lithotripsy are too large to pass through the operating channel of cystoscopes commonly used for dogs and cats. The ballistic lithotripter is too rigid to traverse the curvature of the male urethra. When treating humans, the safety and efficacy of electrohydraulic lithotripsy was inferior to holmium:YAG laser lithotripsy.[2] Because of the versatility and safety of laser lithotripsy, and the authors' familiarity with this treatment modality, the remaining discussion focuses on the use of holmium:YAG laser lithotripsy to manage urocystoliths and urethroliths in companion animal practice.

What Is the Origin of Intracorporeal Laser Lithotripsy?

The term "laser" is an acronym for Light Amplification by Stimulated Emission of Radiation. A laser is a device that transmits light of various frequencies into an extremely intense, small, and nearly nondivergent beam of monochromatic radiation with all the waves in phase. Lasers are capable of mobilizing immense heat and power when focused in close range.

Use of laser energy for intracorporeal lithotripsy is a relatively new concept. In 1968, investigators first reported in vitro fragmentation of uroliths with a ruby laser.[3] Because fragmentation of stones was associated with generation of sufficient heat that would likely damage adjacent tissues, however, it could not be used to treat patients. Likewise, use of carbon dioxide laser energy was considered unsuitable for clinical use because it could not be delivered through nontoxic fibers or through a liquid medium. In 1986 using a 504-nm pulsed dye laser, researchers successfully and safely treated human patients with ureteroliths.[4] The holmium:YAG laser is one of the newest and safest lasers available for clinical lithotripsy.[5,6]

What Is the Origin of the Name Holmium: YAG Laser Lithotripsy?

Holmium (Ho) is a rare earth element named after Sweden (the Greek word "holmia" means Sweden) in honor of the Swedish chemist who discovered it. A holmium:YAG laser is a laser whose active medium is a crystal of yttrium, aluminum, and garnet (YAG) doped with holmium (chromium and thulium), and whose beam falls in the near infrared portion of the electromagnetic spectrum (2100 nm). Several commercial models of holmium:YAG lasers for lithotripsy are available. The pulse duration ranges from 250 to 750 microseconds, the pulse energy ranges from 0.2 to 4.0 J/pulse, the frequency ranges from 5 to 45 Hz, and the power output ranges from 3.0 to 100 W. The power that one chooses is based on the desired application. The holmium:YAG laser that we use has a maximum power output of 20 W with a 350-microsecond pulse width (**Fig. 1**).

How Do Holmium: YAG Lithotriptors Fragment Uroliths?

The mechanism of stone fragmentation with the holmium:YAG laser is mainly photothermal, and involves a thermal drilling process rather than a shock-wave effect.[7] Laser energy is transmitted from the energized crystal to the urolith by way of a flexible quartz fiber. With each pulse, water at the tip of the laser fiber is vaporized creating a vapor bubble that when transmitted to the urolith causes thermal decomposition. Rapid expansion and collapse of vaporization bubbles shear the stone into fragments. To achieve optimum results, the fiber tip should be in direct contact with the surface of