Urologic Applications of the Holmium Laser

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Since its introduction in 1990, the holmium laser has proven its versatility. The holmium laser was first introduced for use in orthopaedics and has progressed to use in many other services including urology. The use of the holmium laser in urology has expanded to include treatment of calculi, urothelial tumors, strictures, condyloma, meteuroceles, as well as other soft tissue applications, possessing both ablative and hemostatic properties.

Laser Physics  
Laser is an acronym for Light Amplification by Stimulated Emission of Radiation. The term is now used for laser devices that produce an intense coherent, directional beam of light by stimulated electronic or molecular transitions to a lower energy level. Each atom has a nucleus containing positively charged protons. Negatively charged electrons orbit the positively charged nucleus. The usual charged state of the atom is balanced. The orbit of each electron is associated with a specific energy level. The ground state finds the electrons and protons close together in a low energy state. To change electrons to a higher level, energy from outside the atom is required. Stimulating the atoms with an outside source of energy excites electrons, “kicking” them to a more distant orbit of higher energy. “Excited” electrons harbor extra energy. When electrons “drop” back down into their ground state there is a spontaneous emission of light radiation (a photon) from the “excited” atom. When many “excited” atoms are collected in a tube, their emissions of energy are amplified, and emerge as a laser beam. Different lasers take their names from the energy sources that are used to excite the atoms.

The medically utilized holmium laser emits a pulsed beam of 2,100 nm (nanometers) with a maximum power output of 60 watts. The laser energy is delivered via a quartz fiber, either an end-firing or side-firing refractive 5.5 Fr fiber. There are four different sizes of end-firing fibers: 200, 365, 550, and 1,000 micron diameters, and one angled side-firing fiber. The energy is dispersed by both direct contact and noncontact modes. The fiber for the noncontact mode must be kept less than 5 mm away from the tissue for tissue response. The beam’s energy transmission is noncolor selective and thermal damage is only 0.4 mm to 0.6 mm. The laser is portable and does not require water hookups. It does require special electrical power, most often 208-volt, 30-amp, single-phase power.

Laser Safety  
Basic laser safety should always be practiced when using any laser. The holmium laser is a class IV laser. These lasers pose hazards to eyes and skin. Precautions to be taken when using a class IV laser include using appropriate eyewear, labeling doors, and covering any windows while the laser is in use. Water should be readily available. One should also have a fire extinguisher available. Instruments used in the vicinity of the laser must be anodized or have a roughened surface in order to avoid reflection which could produce unwanted damage in a nontargeted area. Endotracheal tubes can be ignited by the laser if they are flammable and come in contact with the laser beam. Laser-resistant endotracheal tubes should be used when the laser treatment area is close. Laser plume can also be a concern. Different institutions have additional policies. At our institution the laser safety officer

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enforces the safety measures that protect the patient and staff during laser use.

**Use in Urology**

The first urologic use of the holmium laser dates to 1993 when ureteric calculi were treated by laser vaporization. Stone disease involves approximately 10% of the typical urology practice. There are several different types of stones. Calcium oxalate and calcium phosphate compose 80% of renal and ureteral calculi. Oxalate stones are divided into dihydrate and monohydrate. The noncalcium calculi include cystine, struvite, and urate.

The holmium laser is very effective on all types of calculi (Shoff et al., 1996). Following appropriate evaluation including radiologic study to determine the presence, location, and size of a calculus, the urologist must decide the proper treatment. Small caliber flexible and semi-rigid ureteroscopes, combined with newer, slimmer laser fibers make laser treatment of distal calculi common and often desirable. Access to the stone is obtained by a variety of means. Depending on surgeon preference, the ureteral orifice may or may not be dilated prior to ureteroscopy. A guide wire is inserted into the ureter. Obstruction of the ureter by the stone may present difficulty; thus, a guide wire or other type of hydrophilic wire is used to gain access to the kidney. Once access to the kidney is obtained, the surgeon may opt to dilate the ureter with a balloon dilator, dilating ureteral catheter, or a dual lumen ureteral catheter. A second guide wire may then be inserted. If a second wire is inserted, the surgeon may then pass the ureteroscope over the second wire. If no second wire is used, the surgeon will pass the ureteroscope alongside the guide (safety) wire. Care is taken never to lose access to the kidney. Once the calculus is visualized, the laser fiber is passed through the working channel of the ureteroscope. Laser fragmentation of the calculus is often begun with low power settings such as 0.6 joules at 6 Hz (hertz). If the calculus does not respond, the power or frequency may be increased. Adjuncts to treatment include placing the patient in a reverse Trendelenburg position to keep the calculus from migrating proximally up the ureter into the kidney pelvis during lithotripsy. Once the calculus has been fragmented to a manageable size, the surgeon may then either discontinue treatment, place a ureteral stent, or basket the stone, then place a stent.

Bladder calculi have always presented problems with treatment secondary to their large size (see Figures 1 & 2). A bladder stone can grow to such a size that it may require removal by an open surgical procedure. The holmium laser has proven quite useful in treating bladder calculi (Grasso, 1996). Either an end-firing or the side-firing fiber can be used to fragment the stone. Depending on size and composition, laser settings may vary. A beginning setting may be 0.6 to 1.0 joules with a pulse rate of 6 to 10 Hz. If that setting makes the stone “jump” too much, the pulse rate may be lowered. Different techniques may be used to get the bladder calculus to a manageable size. Slowly “painting” the calculus edges with the laser fiber to reduce the calculus layer by layer may be preferred to breaking the calculus into smaller pieces. As the calculus is reduced in size it “jumps” more in the bladder causing more irritation to the bladder lining. Stone fragments must be totally irrigated from the bladder, often with an instrument such as a Toomey and adapter or an Ellick and adapter. Once all fragments are removed, a catheter may be inserted to prevent urinary retention.
The holmium laser also has use in treating urethral and ureteral stricture disease (Razvi, Chun, Denstedt, & Sales, 1995). There are a number of causes of urethral strictures. Trauma and sexually transmitted disease are the most common. Strictures vary in size, length, and depth. When pursuing treatment of a urethral stricture it is desirable to gain access to the bladder before beginning laser treatment. This may be accomplished by using a guide wire, filiform, or ureteral catheter. An angled or end-firing fiber may be used as the cutting tool. The proximity to the sphincter should be identified. With the fiber extended from the cystoscope, a 12 o’clock incision is made into the urethral stricture. This may be accomplished with an end-firing fiber by positioning the fiber into the tissue at the 12 o’clock position and dragging it through the tissue toward the cystoscope. When using the angled fiber it is positioned at 12 o’clock directly on the tissue and dragged toward the cystoscope. Similar cuts are made either in the same position or rarely at the 6 o’clock position until access to the bladder can be made with the cystoscope. Power is increased as the density of the scarred tissue becomes evident by its response to the laser. Laser settings usually start at 1 joule and a frequency of 10 Hz. Once the bladder is inspected, the urethrotomy is again assessed to assure acceptable patency and hemostasis. When it is determined that the stricture is opened sufficiently, a catheter or Urolume prosthesis is placed. If the Urolume prosthesis is used a catheter is contraindicated.

The holmium laser has also been used on ureteral strictures (see Figures 3-5) (Razvi et al., 1995). The laser is used much the same way it is for a ureteral calculus. A retrograde pyelogram is done to determine the location and length of the ureteral stricture and rule out other pathology. A guide wire is placed up into the affected ureter. A ureteroscopy is performed and once the ureteroscope reaches the stricture site the laser fiber is advanced into the strictured area then dragged back toward the ureteroscope. Laser settings start at 0.6 joules with a rate of 6 to 10 Hz. After the stricture has been incised a ureteral stent is placed.

The holmium laser has also been used to incise ureteroceles. The incidence of ureteroceles is as high as 1 in 500 (Coplan & Duckett, 1995). These congenital malformations are cystic dilations of the submucosal portion of the intervesical ureter. They are thus often not recognized unless other symptoms such as infections occur which would then necessitate treatment. Urerteral calculi may also form in ureteroceles. In adults, they are usually associated with a single collecting system. Treatment requires placing a ureteral guide wire followed by laser incision of the uretercele. An end or side-firing fiber can be used. Laser settings range from 1.0 to 1.2 joules at a rate of 10 Hz. Once the uretercele is incised and any calculus is extracted, a ureteral stent is placed.

Soft tissue holmium laser applications include
laser ablation of tumors, prostate tissue, bladder neck contractures, and condyloma. Concerning bladder cancer, the size and location of the tumor determine which type of fiber can be used. Laser tumor fulguration can be performed with the continuous flow laser resectoscope. Settings for the laser start at 1.0 to 1.4 joules with a rate of 10 to 14 Hz.

Laser ablation of the prostate is used for benign prostate hyperplasia (BPH). BPH affects some 18.5 million men (Razvi et al., 1995). Although the “gold standard” for treating BPH is the transurethral resection of the prostate (TURP), laser fulguration is an accepted alternate treatment. Laser settings for treating the prostate start at 1.8 to 2.0 joules with a rate of 25 to 30 Hz. Again a continuous flow laser resectoscope may be used with the side-firing fiber. A side-firing fiber should also be used for incision of bladder neck contractures. Laser settings are usually 1.2 to 1.4 joules with a rate of 10 to 14 Hz.

Laser fulguration of genital and urethral condyloma is also practiced. The depth of laser effect is 0.4 to 0.6 mm. Treatment settings begin at 0.6 joules with a rate of 10 Hz. A rate of 15 Hz should not be exceeded. The fiber can be hand held or a laser hand piece can be used. Precautions pertaining to laser plume and condyloma should be instituted. These precautions include use of a smoke evacuator and special laser plume masks along with the other laser safety policies (“The Dangers of Laser Plume,” 1990).

**Conclusion**

The holmium laser has proven to be of great use in urology. As with other lasers, care should always be taken, but the holmium seems to be one of the safest lasers to use if the proper precautions are taken.

**References**


