Lasers in Urology

Physical properties: laser-tissue interaction

- **Absorption**: the most important factor in laser-tissue interaction. Its direct effect is the generation of heat in the tissue. Depending on the amount of heat generated, the result will be either coagulation or vaporization. As the laser beam penetrates an absorbing medium, its intensity decreases exponentially. Its effect is therefore greater in tissue close to the surface of contact. In order to produce absorption, it is necessary to have a chromophore (energy-absorbing particle). In urological applications of laser technology, the two chromophores available in the human body are water and hemoglobin.

- **Reflection**: percentage of the laser beam that is reflected upon interacting with tissue. This causes the beam to lose efficiency and raises the risk to the surrounding tissue, which could suffer an unwanted rise in temperature. Reflection of a given laser depends on the optical properties of the tissue and the irrigation fluid.

- **Dispersion**: from an optical point of view, body tissue is not homogeneous, causing dispersion when the laser beam interacts with it. This dispersion depends on the size of the tissue particles and the wavelength of the laser. Lasers with shorter wavelengths tend to exhibit more dispersion.

Lasers in the treatment of BPH

- **Nd:YAG laser (Neodymium: Yttrium-Aluminum-Garnet)**:
  - **Characteristics**: has the greatest penetrability (4-18mm), with a wavelength of 1064 nm. Mainly used for tissue coagulation, it has been utilized in the treatment of BHP (visual laser ablation of the prostate, VLAP).
  - **Indications**: prostates up to 50-60 g. Contraindicated in patients with either chronic prostatitis or recurrent infection because of the high probability of infection of the necrotic tissue.
  - **Results**: its use is discouraged due to its poor results.

- **Diode laser (interstitial coagulation)**:
  - **Characteristics**: its wavelength ranges from 808-980 nm. The absorption effect in water and tissue is similar to that of the Nd:YAG laser. It produces necrosis by means of coagulation in the adenoma, causing secondary atrophy and regression of the prostatic lobes. Does not allow for collection of tissue for biopsy. Its main advantages are its smaller size and greater energy efficiency.
  - **Results**: the results have been good, with improvements in IPSS, Qmax, and residual volume. However, patients treated with this type of laser present intense postoperative irritative symptoms and require prolonged periods of catheterization. The re-treatment rate is 15.4% in the first year, 3.1% per year in the years immediately following, and 9.6% in longer follow-up periods.

- **KTP (potassium, titanyl, phosphate) laser, green light 80 W laser, or HPS (High Performance System) 120W laser (lithium triborate)**:
  - **Characteristics**: these lasers are derived from Nd:YAG lasers. Their wavelength is 532 nm and their penetrability is 667-835 μm. The chromophore used is hemoglobin, with minimal absorption by water. Tissue is destroyed through vaporization. In vascularized tissues the absorbed energy is high, permitting higher temperatures up to the boiling point. The tissue is vaporized, leaving an external coagulated layer. This layer, upon reducing the energy absorption of the tissue, increases the beam spread, thereby reducing the vaporization efficiency in inner layers of tissue.
  - **Recent modifications**: the latest model is the green light XPS (Xcelerated Performance System), with an output of 180 W, more efficient vaporization, and similar penetrability.
  - **Results**: 3-year prospective studies have demonstrated its efficacy and durability.
• Holmium:YAG laser:
  - Characteristics: with a wavelength measuring 2140 nm, its penetrability is limited to 400 μm; absorbed by water.
  - Mechanism of action: predominantly photothermic, this laser requires direct contact with tissue to optimize its effect. It has two applications:
    - Enucleation (HoLEP): at maximum power it produces an intense vaporization of the tissue with precise and efficient cutting. The technique consists of retrograde enucleation of the prostatic adenoma and its subsequent fragmentation (morcellation) in the bladder to facilitate its removal. The results are similar to those of TURP or open surgery, but with a longer operation time. Its main advantages are shorter catheterization times and less lengthy hospital stays.
    - Ablation (HoLEP): with a wavelength of 532 nm, this laser is indicated for prostates <40 mL. It allows for rapid removal of the catheter, often on the same day as surgery.
  
• Thulium laser:
  - Characteristics: with a wavelength tunable between 1.75 and 2.22 μm, this laser has high absorption by water with low penetration depth. Tissue ablation speed is faster than with a KTP laser. Allows for collection of tissue for histological analysis.
  - Results: similar to those for enucleation via Holmium laser with regard to both efficiency and complications.

Lasers in the treatment of urinary lithiasis

• Holmium:YAG laser: with a wavelength measuring 2140 nm and a penetrability limited to 3-4 mm, this laser is absorbed by water.
  - Mechanism of action: because it is predominantly photothermic, this laser requires direct contact with the stones for optimal effect. A channel is formed by laser-induced vapor between the fiber and the stone, allowing direct irradiation of the stone and an increase in temperature. This provokes the chemical degradation of the stone, which favors its fragmentation by means of the vapor bubble and the expansion of interstitial water. This mechanism produces a minimal propulsion effect.
  - Technique: often used at frequencies between 5-10 Hz. Higher frequencies (20-40 Hz) cause the popcorn effect, which is useful in small renal cavities with multiple smaller stones and precludes the need for establishing direct contact between the fiber and the stone.
  - Results: the fragmentation rate is 100%, regardless of the nature of the stone. The stone-free rate is likewise 100% in the distal ureter, 97.7% in the iliac ureter, and 70.3% in the proximal ureter. In renal cavities (with flexible material), the stone-free rate is 92.2% after an average of 1.3 sessions per patient.

• FREDDY laser: a double frequency, double pulse Nd:YAG laser. Its wavelength ranges from 1064 to 532 nm.
  - Mechanism of action: fragmentation through the generation of a plasma bubble.
  - Technique: the retropulsion generated and the resulting fragmentation is greater than that produced by the Holmium laser, although it is ineffective for cystine stones and only minimally effective in calcium oxalate monohydrate stones. This laser does not have applications in tissue.

• Other lasers:

<table>
<thead>
<tr>
<th>Laser</th>
<th>Fragmentation(%)</th>
<th>Stone free rate(%)</th>
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<tbody>
<tr>
<td>Alexandrite</td>
<td>93</td>
<td>90</td>
</tr>
<tr>
<td>Pulsed Dye laser</td>
<td>97</td>
<td>61-91</td>
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<tr>
<td>N: YAG</td>
<td>83.5-94</td>
<td>90</td>
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<tr>
<td>Holmium</td>
<td>100</td>
<td>85-100</td>
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Other applications of lasers in urology

- **Stenosis and obstruction of the UPJ (Holmium laser):**
  - *Retrograde or antegrade endopyelotomy:* allows precise incisions through the entire tissue thickness and under direct vision. Can be combined with pneumatic dilation. Success rates are 70-97% when patients are properly selected (short stenotic segments with no major pyelic dilations).

- **Ureteral stenosis (Holmium laser):** retrograde access is preferable. The incision varies depending on the location of the stenosis:
  - *In the iliac ureter* an upper incision should be made (risk of injury to the iliac vessels).
  - *In the proximal ureter,* a lower incision is better (risk of injury to aberrant vessels).

- **Laparoscopic pyeloplasty:** laser soldering utilizes the photothermic properties of laser light and applies them to a solder (50% human *albumin*) together with specific *chromophores*, depending on the wavelength used to facilitate the absorption of the laser beam. The technique was developed to simplify ureteropelvic reconstruction; however, it has shown no advantages over conventional suturing techniques. It is therefore not recommended in clinical practice.

- **Laser laparoscopic partial nephrectomy:** most studies on this technique have been conducted in animal models. There is insufficient evidence to recommend its use in humans.

- **Laser laparoscopic and robotic radical prostatectomy:** to date, the use of laser energy has not been shown to be beneficial or superior in any way to conventional techniques in this procedure.

- **Urothelial tumors:** electrocoagulation of small tumors can be performed with a *Holmium* or *Nd:YAG* laser. Not recommended for primary tumors, only small recurrences of superficial, low-risk tumors.