
MINERVA

GINECOLOGICA

VOLUME 68 · No. 6 · DECEMBER 2016



EDIZIONI · MINERVA · MEDICA

PUBBLICAZIONE PERIODICA BIMESTRALE - POSTE ITALIANE S.P.A. - SPED. IN A. P.D.L. 353/2003 (CONV. IN L. 27/02/2004 N° 46) ART. 1, COMMA 1, DCB/CN - ISSN 0026-4784 TAXE PERÇUE

REVIEW

The use of laser in hysteroscopic surgery

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ABSTRACT

The term laser, an acronym for light amplification by stimulated emission of radiation, covers a wide range of devices. Lasers are commonly described by the emitted wavelength that covers the entire light spectrum from infrared to ultraviolet and the active lasing medium. Currently, over forty different types of lasers have found application in medicine. Moreover, advances made by gynecologists in the field of operative hysteroscopy have developed a very great interest in the use of surgical lasers. Technical improvements in hysteroscopes and lasers have led several gynecologists to evaluate their use in the surgical treatment of intrauterine pathologies. This narrative review concerns the most common used lasers in hysteroscopic surgery with particular attention to the latest promising results of the laser technology.

(Cite this article as: Nappi L, Sorrentino F, Angioni S, Pontis A, Greco P. The use of laser in hysteroscopic surgery. Minerva Ginecol 2016;68:722-6)

Key words: Hysteroscopy - Gynecologic surgical procedures - Laser therapy.

Light amplification by stimulated emission of radiation, commonly referred to as laser, describes a wide range of devices. Stimulated emission was based on Einstein's quantum theory of radiation. Lasers are used in a wide range of applications in medicine and they can be categorized according to these characteristics: 1) wavelength (lasers span the entire light spectrum from infrared to ultraviolet); 2) power (the power output ranges from a milliwatt to millions of watts); 3) output beam (the laser output may be continuous where the lasers emit light in a continuous manner or pulsed, where the lasers emit light in short impulses).¹

In gynecology the first use of laser technology (CO₂ laser) was for treatment of cervical erosions, then for the treatment of CIN (cervi-

cal intraepithelial neoplasia) and microsurgery of the fallopian tube.²⁻⁴ Laser technology has made many advancements and over 40 types of laser are now available, including the latest semiconductor diode lasers. Laser technology has also been widely used in laparoscopy, and in particular in infertility surgery.⁵ Moreover, advances made by gynecologists in the field of operative hysteroscopy have created a very great interest in the use of surgical lasers. Improvements in optics, light sources, hysteroscopes, and lasers have led several gynecologists to investigate the use of lasers for intrauterine surgical procedures. The primary use of laser in hysteroscopy has been in the treatment of menorrhagia with the neodymium:yttrium aluminium garnet

(Nd:YAG) laser.⁶ To date, four surgical lasers have been evaluated for hysteroscopy surgery: CO₂, Nd:YAG, argon, and potassium titanyl phosphate (KTP) lasers. More recently, the use of diode lasers has been observed in almost every area of medical sciences with very promising results in hysteroscopic surgery. This review focuses on the physics and applications of commonly used lasers in hysteroscopic surgery with particular attention to the latest promising results of the laser technology.

Physics of laser

A laser (acronym for Light Amplification by Stimulated Emission of Radiation) is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. This concept was developed in 1917 by Einstein who described a phenomenon whereby light could liberate electrons from certain metal surfaces (the photoelectric effect).⁷ The first laser specimen was made by Theodore Maiman in 1960. Essentially, a laser system is made with an active medium that can be a gas, a crystal or a liquid and a source of energy to pump this medium. The medium is placed between two mirrors that have particular characteristics: they are optically parallel and highly reflecting. There are gas (CO₂ and argon), solid-state (Nd:YAG and KTP:YAG), metal vapour (copper and gold vapour), diode and free-electron lasers. Metal vapour lasers operate at low wattages.⁸ The diode laser is based on the production of light by an electronic component called a diode and they utilise semiconductors to fill in the gaps between anatomic energy levels.⁹ The interaction between laser and tissue can have different effects including photothermal, photochemical and photoacoustic. The photothermal effect with the conversion of energy to heat is the most common application of laser in gynecology. The actual effect observed in tissue depends on the quantity of energy delivered, the wavelength of the laser, and the absorption coefficient of the tissue.¹⁰

Different types of laser

The main existing laser categories are classified according to the material that constitutes the active medium. We can classify lasers used in biomedicine in three categories:

- gas laser;
- solid-state laser;
- diode laser.

CO₂ laser

This is one of the first lasers to be developed in 1964. This is a gas laser which produces a beam of infrared light with a wavelength of 10,600 nm. The lasing medium is a combination of helium, nitrogen and CO₂ and the external energy source is usually either an electrical charge or a radio frequency field.⁸ Its limited depth of penetration (0.1-0.5 mm) makes it one of the most safe and versatile medical laser. The CO₂ laser is highly absorbed by water so deep penetration is prevented, as long as there is intra and extracellular water to be vaporised.

Nd:YAG laser

This solid-state laser uses a neodymium-doped yttrium aluminium garnet crystal. It can produce different wavelengths but the most common emission wavelength is 1064 nm. Because its energy is poorly absorbed by water, there is on average a depth of penetration of 3-4 mm. It can operate in continuous or pulsed modes and it can be transmitted through quartz fibers (the bare quartz fiber and the quartz fiber with a sapphire contact tip that needs to be cooled).¹¹

KTP laser

The KTP-532 laser (also known as green-light laser) is made with a potassium titanium oxide phosphate (KTP) crystal which doubles the frequency of Nd:YAG laser energy to a 532 nm wavelength (in the green electromagnetic spectrum). It is selectively absorbed by hemoglobin and not at all by other chromophores

(water or non-pigmented tissue).¹² It has limited depth of penetration (from 0.3 to 1 mm) and it is used for homeostasis or vaporization of pigmented tissue.

Argon laser

Argon laser is one of the mostly used ion gas lasers. It typically produces several watts power of a green or blue output beam.¹³ Its wavelengths (the most common emission is 514 nm) are absorbed by many tissue chromophores (like hemoglobin) so this laser has hemostatic properties. The hemostatic effect is achieved through the heating of blood and vessel walls.

He:Ne laser

The helium neon (He:Ne) laser is a type of small gas laser which has an active medium consisting of two gases, which do not interact with each other. It can emit at various wavelengths (543, 594, and 632.8 nm)¹⁴ but the most widely used wavelength is in the red portion of the visible spectrum at 632.8 nm. The He:Ne laser system is used for many medical treatments.¹⁵

Diode laser

Semiconductor lasers or diode lasers are realized by means of semiconductor junctions (p-n junctions). Using certain junction geometries and highly efficient microstructures the continuous electric current that passes through the active medium can be turned into a laser radiation. Different combinations of semiconductors allow to obtain different wavelengths in the output of a broad spectrum. Diode lasers, like most other lasers, incorporate an optical gain medium in a resonant optical cavity.¹⁶ They produce wavelengths from 980 to 1470 nm. These wavelengths issued simultaneously confer a contemporary absorption in hemoglobin and H₂O and therefore excellent ability of hemostasis, cutting and vaporization. Compared to the CO₂ laser, the diode laser creates a significantly higher hemostasis.

The thermal penetration of the diode laser is smaller compared to the Nd:YAG laser and then surgery is precise and safe also close to delicate anatomical structures. The diode laser is the most widely used in biomedicine thanks to its intrinsic characteristics:⁹

- it has a high efficiency in transforming the electric current in the laser light;
- the resonant cavity of the diode laser is very small, allowing the realization of little and easily transportable generators;
- the semiconductor laser can deliver power continuously with an efficiency more than 50% (power consumption per 10 W of power output: 5 W);
- the pulses are easily dispensed by modulating the input current to the laser diode.

Optical fibers

The optical fibers are very small wires (from a few microns up to more than a millimeter) of dielectric material capable of transmitting laser radiation with a frequency range that goes from infrared to ultraviolet. The optical fibers represent the ideal medium for transmitting laser radiation from the source to the target. In the biomedical field, quartz fibers are used because they ensure maximum transmission and the range of wavelengths from 250 to 2400 nm. The optical fibers can have different diameters and terminations. The diameter is directly related to laser power that can be conveyed. The shape of the terminations determines the geometry of the laser emission.¹⁷

Laser applications in hysteroscopic surgery

The use of laser in hysteroscopic surgery has many different applications including endometrial ablation, resection of myomas and polyps, septoplasty and synechiolysis. The first laser photovaporization of endometrium using Nd:YAG for the treatment of menorrhagia was reported in 1981.¹⁸ Hysteroscopy has been used for many years as a diagnostic instrument to evaluate abnormal uterine bleeding and now it is possible to use this technology as a therapeutic modality for patients with

recurrent menometrorrhagia. Many different instruments can be used with the hysteroscope including scissors, electrodes and laser fibers. The Nd:YAG laser fiber is very flexible and it can be passed easily through the working channel of an operative hysteroscope. Nd:YAG laser can be employed for hysteroscopic removal of submucous myomas and polyps, resection of uterine septum, lysis of intrauterine adhesions. The treatment with laser vaporization using an Nd-YAG and KTP laser has also been described in the treatment of Asherman's Syndrome.^{19, 20} Complications from hysteroscopy are very relatively rare events and include bleeding, uterine perforation/damage to cervix, fluid overload, infection, pelvic inflammatory disease and laser injuries. The use of a sapphire tip with the Nd:YAG laser must be avoided: some authors have reported deaths caused by air embolism associated with Nd:YAG laser surgery and artificial sapphire tips.²¹

Advancements in laser technology applied to hysteroscopy

Thanks to the continuous and incessant developments realized in the last 20 years, hysteroscopic surgery has become safer and less invasive for the patients. The ongoing developments and improved technology have enabled us to perform many operative procedures in an ambulatory setting, with no patient discomfort and with potentially significant cost savings. Indeed, hysteroscopy is now considered the gold standard for treating a number of benign uterine disorders including polyps, synechiae and myomas.^{22, 23} The trend to perform minimally invasive procedures has led to the development of very interesting applications in office hysteroscopy. One of this application is the laser technology. Recently, diode lasers have had a great development for a variety of medical applications especially surgery thanks to their miniature size, cost effectiveness, relative simplicity of use and the range of available wavelengths.²⁴ The currently available 980 + 1470 nm diode laser has been used recently in laparoscopic surgery with many

advantages.²⁵⁻²⁷ Similarly, the use of laser diode instead of the standard bipolar energy has given promising results in the office hysteroscopic resection of submucous myomas and endometrial polyps. Preliminary results show the surgery is cleaner with the diode laser, without the production of bubbles induced by ionization effect. Moreover, this new laser enables to respect surgical planes and it is able to tackle diseases in locations not easily accessible (for example tubal corners of the uterus). The clinical advantages can be rapid recovery and low-rate injuries and postoperative complications.²⁸⁻³¹ Recently some authors compared outpatient hysteroscopic polypectomy performed with Versapoint bipolar electrode and diode laser. Polypectomy with diode laser resulted in fewer relapses and a higher procedure satisfaction rate as compared to Versapoint.³²

Conclusions

Laser technology in gynecology was first used for treating cervical lesions. Over the time, four surgical lasers (CO₂, Nd:YAG, argon, and KTP) have been used with hysteroscopy. The development of new laser technology (diode laser) associated with the great improvements in hysteroscopy has led to new interesting therapeutic applications. The preliminary results seem to be very promising but further studies are needed to evaluate the advantages of this new technology compared to traditional electrosurgery.

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Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Article first published online: February 23, 2016.