Laser/Application

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In medicine

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Generally, lasers are used in biomedical research, medical diagnosis, medical therapy, and treatment. Its use started in the second half of the twentieth century, with ophthalmology being the first speciality to utilise it, and soon spread to many other specialities such as dentistry, dermatology, surgery, or oncology as well. Nowadays, its importance continues to grow and new ways of its usage are being researched.

Models of laser-tissue interactions

Laser radiation interacts with biological tissue. Depending on the **energy** of the laser beam, **exposure time** and **wavelength** this interaction results in:

Photoablation occurs when high-energy laser wavelengths in the ultraviolet region of the spectrum are used to break long-chain tissue polymers into smaller volatile fragments. The exposure times of this process are in nanoseconds. Excimer lasers work on this principle.

Photocoagulation uses the **thermal energy** of a laser. Tissues on which laser is applied shrink in mass because water is expelled from them, change colour and lose their mechanical integrity. Cells in the photo-coagulated area die and a region of dead tissue called **photocoagulation burn** is produced.

Photocoagulation is used to destroy tumours or while treating various eye conditions (e. g. retinal disorders caused by diabetes) or during **haemostatic laser surgeries** to produce almost bloodless incisions or to stop vessels from bleeding. A leaking blood vessel subjected to photocoagulation develops a pinched point due to shrinkage of proteins in its wall. The coagulation restriction helps seal off the flow, while damaged cells initiate clotting.

Photomechanical (photodisruptive) mode requires nanosecond or shorter pulses with extremely high spatial density of photons. The **Nd YAG lasers** work on this principle.

Photochemical reactions (photodynamic therapy) are processes bound to the wavelength of the laser beam and are used mainly in photochemotherapy. The photodynamic therapy reaction is mediated by **exogenous chromospheres**. At low light intensities, laser energy is absorbed by these exogenous chromospheres molecules called **photosensitizers**. The molecules or drugs are then activated by the laser light of the **specific wavelength**. The absorbing molecule can transfer the energy to another molecule and this activated molecule can then cause chemical reactions in the surrounding tissue. Photodynamic therapy is mainly used in **treatment of tumours**.

Photovaporisation occurs when higher energy laser light is absorbed by the target tissue, resulting in vaporisation of both intracellular and extracellular water. The adjacent blood vessels are also treated while using this method, resulting in a nearly bloodless surgical field. The **carbon dioxide laser** uses this method of action.

Advantages of laser

Less invasive method of treatment that leaves minimal scarring of the tissue and enables it to heal faster.

Lasers also enable surgeons to work with **higher precision** to produce a very thin and small incision and increase the **sterility**.

Disadvantages of laser

Disadvantages of lasers include its **high cost**, the need for special training of those who are using it and also the need of a **special anaesthesia**.

Factors influencing laser choice

Each medical speciality requires a different laser. Choosing a suitable one for a given application (given tissue) is crucial and depends on both properties of the tissue as well as of the laser. When choosing a suitable laser we look at the absorptive characteristics of the tissue to be destroyed, t**he wavelength of the emitted radiation**, the temporal parameters of the delivered energy including the **power density, energy density** and **pulse repetition** (rate and duration of the exposure) and the mode of beam energy delivery to a target tissue (continuous/pulsed energy and direct/no contact with the target tissue).

Types of lasers

According to the wattage of the laser beam, we distinguish two main types of lasers - noninvasive **therapeutic lasers** with wattage up to 500 mV and invasive **surgical lasers** with a wattage of more than 1 W that are used in various surgical specialities. In the area where the laser beam is absorbed luminous energy is transformed into thermal and mechanical one and can even induce a chemical reaction.

Lasers with shorter wavelengths (627 - 780 nm) are used in dermatology, gynaecology and stomatology, lasers with longer ones are used mainly in rehabilitation and neurology.

Types of lasers used in surgery

Argon lasers are primarily used in ophthalmology. The blue light of argon lasers is absorbed by blood, therefore they are used for photocoagulation of small blood vessels.

Carbon dioxide lasers are used in a number of surgical fields as laser scalpels. CO_2 lasers have many advantages - they produce a very thin incision and as a result of the photocoagulation of capillaries also minimize bleeding during the surgery.

Dye lasers are used in dermatology and gastroenterology. The laser beam of the dye laser causes a fragmentation of biliary and kidney stones. Because of the tunability of their wavelengths, dye lasers are also used in diagnostics to elicit fluorescence or phosphorescence in examined molecules.

Excimer lasers (KrF, ArF) emit UV radiation and produce an extremely neat incision. Because of that, they are used during angioplasties to clear clogged blood vessels. Excimer lasers are also used in ophthalmology to correct myopia and astigmatism.

Neodyme lasers are used mainly in gastroenterology. They are inserted endoscopically into the alimentary canal to stop a bleeding or to clear the GIT of patients with inoperable conditions.

Use of laser in particular medical specialities

Dentistry

In dentistry, there is a significant application of powerful lasers that produce short wavelength radiation. They are used instead of dental drills. There is a wide use of lasers in treatment of inflammatory diseases, periodontitis, tooth hypersensitivity or tooth demineralisation.

Usage of lasers in dentistry has many advantages, such as decreased postoperative swelling which allows for increased safety when performing surgeries within the airway. Thin lease beam increases the range of surgeries that can be safely performed.

Dermatology

There is a wide use of lasers in dermatology. Many types of skin conditions such as vascular lesions, pigmented lesions, tattoos, facial wrinkles, scars, sun-damaged skin, bedsores (decubitus ulcers) are frequently treated with laser. It is also commonly used for biostimulation of body cells which leads to fast, effective, and comfortable treatment of congenital malformations.

Surgery

The growth of laser technology in the last couple of decades led to the development of new medical field – laser surgery. Examples include the use of a laser scalpel in otherwise conventional surgery and soft-tissue laser surgery, in which the laser beam vaporises soft tissue with high water content.

The CO_2 (carbon dioxide) laser remains the gold standard for the soft tissue surgery because of the ease of simultaneous photo-thermal ablation and coagulation (and small blood capillary hemostasis). Types of surgical lasers include carbon dioxide, argon, Nd:YAG laser, and Potassium titanyl phosphate, among others.

Surgery uses lasers for coagulating, vaporising, and cutting. However, each medical specialty has different requirements and thus prefers diverse types of lasers with different parameters.

Visible wavelength and Nd YAG lasers are used for **prophylactic haemocoagulation** to prevent and control bleeding in small vessels and vascularized target tissue. This method requires a lower energy density which can be achieved either by enlarging the spot size or lowering the absolute power or exposure duration.

To remove tissue mass (primarily in tumour excisions) surgeons use vaporisation. To achieve a higher rate of tissue removal a high-power density beams are used in combination with a large spot size.

Pulses are used to achieve the highest possible safety and precision by limiting an off-target beam.

Neurosurgery

The major effect of a laser on neural tissue is **thermal**. Neurosurgery also has a higher use of **stereotactic techniques** because of the smaller openings, reduces brain injury, decreases morbidity and enables a shorter recovery time post surgery.

Oncology

Laser therapy uses high-intensity light to treat cancer. Lasers can be used to shrink or destroy tumours or precancerous growths. Lasers are most commonly used to treat superficial cancers (cancers on the surface of the body or the lining of internal organs) such as basal cell skin cancer and the very early stages of some cancers, such as cervical, penile, vaginal, vulvar, and non-small cell lung cancer.

Lasers may also be used to relieve certain symptoms of cancer, such as bleeding or obstruction. Lasers can be used to shrink or destroy a tumour that is blocking a patient’s trachea or oesophagus. Lasers also can be used to remove colon polyps or tumours that are blocking the colon or stomach. Laser therapy can be used alone, but most often it is combined with other treatments, such as surgery, chemotherapy, or radiation therapy.

In addition, lasers can seal nerve endings to reduce pain after surgery and seal lymph vessels to reduce swelling and limit the spread of tumour cells.

Ophthalmology

Ophthalmology was one of the first specialties to incorporate lasers as a therapeutic and diagnostic modality modality and did so as early as 1961 when Leon Goldman (founder of the American Society for lasers in medicine and surgery) showed how a red beam emitted from a ruby laser could remove melanomas.

Ophthalmology uses the ability of a laser beam to enter the eye without causing an injury. Today, lasers are indispensable for effective and minimally invasive microsurgery of the eye. Oftalmology predominantly uses **ArF lasers**.

In diagnostics of various eye diseases, lasers can be advantageous if conventional methods that use incoherent light sources fail.

Orthopaedics

Lasers can be used to treat patients with herniated discs that are unable to recover using physical therapy as they can vaporise the tissue in the disc, creating a vacuum. This causes the disc to shrink away from the pressed nerve and therefore relieves the pain. Lasers are also used in the following shoulder conditions: rotator cuff tears, impingement syndrome (tendons of the rotator cuff muscles become irritated and inflamed as they pass through the subacromial space), instability of the shoulder caused by subluxations or dislocations or arthritis to release soft tissue, debride labral tears, perform synovectomy (removal of the joint lining), subacromial decompression (removal of the thickened bursal tissue) or Laser Assisted Capsular Shrinkage (LACS).

Urology

In urology, we use lasers to cure many defects. Lasers are used during **lithotripsy** – fragmentation of urinary (or biliary) stones, treatments of benign prostatic hyperplasia (BPH) which is a noncancerous enlargement of the prostate, urothelial malignancies, nephron-sparing surgery or urothelial stricture disease.

Other specialities

Lasers also used in **gynaecology** to speed up the healing of wounds and scars, to remove stretchmarks and also for biostimulation of the tissue. Every mucous membrane is more sensitive to the effects of the laser than the skin, therefore lasers with longer wavelength have to be used.

Lasers have also found use in **rheumatology** owing to their anti-inflammatory effect. Similarly to surgery, laser treatment in rheumatology is combined with other methods of treatment – patients are always on medication.

Diagnostic applications of lasers

Lasers are widely used as tools in imaging and diagnosis: for example, in early detection of cancer and other diseases in patients. Nowadays, laser-based systems are beginning to replace X-rays as laser imaging poses less risk for the patient and has proven to be more accurate.

Optical Coherence Tomography (OCT) which uses low-coherence interferometry is already applied in ophthalmology in order to get three-dimensional high-resolution images of the tissues. This enables the ophthalmologist to diagnose retinal diseases or glaucomas.

Other diagnostic applications of lasers include **Laser-induced fluorescence** (LIF) **spectroscopy and imaging** or **Laser Doppler velocimetry** (LDV) which is a non-invasive method that enables the monitoring of microvascular blood flow.

Possible future applications of laser

Possible future applications of lases lie in the area of **photomedicine** that will utilise light-sensitive chemicals in combination with lasers for patients' treatment and diagnosis.

Lasers could also have a great use in personalised medicine as they can operate on different wavelengths that can be altered depending on patient's needs (e. g. skin colour) or in surgery as a replacement of a surgical scalpel, or in biomedical research **(laser tweezers)**.

Outside of medicine

The largest application of lasers lies in **optical storage devices** such as CD or DVD players in which a focused beam from a semiconductor laser that is less than 1 mm wide, scans and reads the disc surface. Lasers are also widely used in **fibre-optic communications** or laser pointers that use inexpensive semiconductor lasers. Lasers can also be used in speed measurement.

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