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Medical Applications of Laser Instruments

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ABSTRACT*:* This paper gives the explanation of different medical applications of LASER instruments in detail. This paper discusses their working principles along with their advantages and limitations. These instruments nowadays are excessively used, and it has made surgery easier. They are used in treatment of cancer, removal of tumors of vocal cords, brain surgery, plastic surgery, gynecology and oncology, etc.
KEYWORDS: Light Amplification by stimulated emission of radiation (LASER), Computerized tomography (CT),Magnetic resonance imaging (MRI),Positron emission tomography (PET), Photodynamic therapy (PDT).

I. INTRODUCTION

The term "laser" stands for light amplification by stimulated emission of radiation. Ordinary light, such as that from a light bulb, has many wavelengths and spreads in all directions. Laser light, on the other hand, has a specific wavelength. It is focused in a narrow beam and creates a very high-intensity light. This powerful beam of light may be used to cut through steel or to shape diamonds. Because lasers can focus very accurately on tiny areas, they can also be used for very precise surgical work or for cutting through tissue (in place of a scalpel). As a result, patients usually have less pain, bleeding, swelling, and scarring.

Laser based instruments are widely used in medical applications. They are used in treatment of cancer, removal of tumors of vocal cords, brain surgery, plastic surgery, gynecology and oncology. Laser therapy causes less bleeding and damage to normal tissue than standard surgical tools do, and there is a lower risk of infection.

Fig.1. CO_2 Laser with applications in ENT, gynecology, dermatology, oral surgery, and podiatry.

Advantages of laser therapy

Lasers are more precise than standard surgical tools (scalpels), so they do less damage to normal tissues. As a result, patients usually have less pain, bleeding, swelling, and scarring. With laser therapy, operations are usually shorter. In fact, laser therapy can often be done on an outpatient basis. It takes less time for patients to heal after laser surgery, and they are less likely to get infections. Patients should consult with their health care provider about whether laser therapy is appropriate for them.

Disadvantages of laser therapy

Laser therapy also has several limitations. Surgeons must have specialized training before they can do laser therapy, and strict safety precautions must be followed. Laser therapy is expensive and requires bulky equipment. In addition, the effects of laser therapy may not last long, so doctors may have to repeat the treatment for a patient to get the full benefit.

II. MEDICAL APPLICATIONS

1. LASER instruments for cancer treatment:

Laser therapy uses high-intensity light to treat cancer and other illnesses. Lasers can be used to shrink or destroy tumors 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 also may be used to relieve certain symptoms of cancer, such as bleeding or obstruction. For example, lasers can be used to shrink or destroy a tumor that is blocking a patient's trachea (windpipe) or esophagus. Lasers also can be used to remove colon polyps or tumors 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 tumor cells.

Lasers have some advantages and disadvantages compared with standard surgical tools.

Advantages of laser surgery

- Lasers are more precise and exact than blades (scalpels). For instance, the tissue near a laser cut (incision) is not affected since there is little contact with skin or other tissue.
- The heat produced by lasers helps clean (sterilize) the edges of the body tissue that it's cutting, reducing the risk of infection.
- Since laser heat seals blood vessels, there is less bleeding, swelling, pain, or scarring.
- Operating time may be shorter.
- Laser surgery may mean less cutting and damage to healthy tissues (it can be less invasive). For example, with fiber optics, laser light can be directed to parts of the body through very small cuts (incisions) without having to make a large incision.
- More procedures may be done in outpatient settings.
- Healing time is often shorter.

Disadvantage of laser surgery

- Fewer doctors and nurses are trained to use lasers.
- Laser equipment costs a lot of money and is bulky compared with the usual surgical tools used. But advances in technology are slowly helping reduce their cost and size.
- Strict safety precautions must be followed in the operating room when lasers are used. For example, the entire surgical team and the patient must wear eye protection.
- The effects of some laser treatments may not last long, so they might need to be repeated. And sometimes the laser cannot remove the entire tumor in one treatment, so treatments may need to be repeated.

Treating cancer with lasers: Lasers can be used in two ways to treat cancer. They are as follows:

a) To shrink or destroy a tumor with heat
b) To activate a chemical – known as a *photosensitizing agent* – that kills only the cancer cells. (This is called *photodynamic therapy* (*PDT*)

a) Shrinking or destroying tumors directly

The CO_2 and Nd: YAG lasers are used to shrink or destroy tumors. They can be used with thin, flexible tubes called *endoscopes* that let doctors see inside certain parts of the body, such as the bladder or stomach. The light from some lasers can be sent through an endoscope fitted with fiber optics. This lets doctors see and work in parts of the body that could not be reached otherwise except by major surgery. Using an endoscope also allows very precise aim of the laser beam.

Lasers can be used with low-power microscopes, too. This gives the doctor a larger view of the area being treated. When used with an instrument that allows very fine movement (called a *micromanipulator*), laser systems can produce a cutting area as small as 200 microns in diameter – that's less than the width of a very fine thread.

Lasers are used to treat many kinds of cancer. In the intestines or large bowel, lasers can be used to remove polyps, small growths that might become cancer. The CO_2 laser can be used to treat pre-cancerous tissue and very early cancers of the cervix, vagina, and vulva.

Lasers are also used to remove tumors blocking the swallowing tube (esophagus) and large intestine (colon). This does not cure the cancer, but it relieves some symptoms, such as trouble swallowing.

The Nd:YAG laser has also been used to remove cancer that has spread to the lungs from other areas. This helps avoid surgery that would require removing large sections of lung. This type of laser cannot cure cancer, but it can improve breathing and other symptoms in many patients.

Cancers of the head, neck, airways, and lungs can be treated (but usually not cured) with lasers. Small tumors on the vocal cords may be treated with lasers instead of radiation in some patients. Tumors blocking the upper airway can be partly removed to make breathing easier. Blockages deeper in the airway, such as in the branches of the breathing tubes (bronchi), can be treated with a flexible, lighted tube called a *bronchoscope* and an Nd:YAG laser.

b) Photodynamic therapy

In photodynamic therapy (PDT), a special drug called a *photosensitizing agent* is put into the bloodstream. Over time it is absorbed by body tissues. The drug stays in cancer cells for a longer time than in normal tissue. Shining a certain kind of light on the cancer cells that have the drug in them "turns on" the drug, which then kills the cancer cells.

Photosensitizing agents are turned on or activated by a certain wavelength of light. For example, an argon laser can be used in PDT. When cancer cells that contain the photosensitizing agent are exposed to red light from this laser, it causes the chemical reaction that kills the cancer cells. Light exposure must be carefully timed so that it's used when most of the agent has left healthy cells, but is still in the cancer cells.

PDT has some advantages over other treatments:

- Cancer cells can be singled out and destroyed but most normal cells are spared.

- The damaging effect of the photosensitizing agent happens only when the drug is exposed to light.
- The side effects are fairly mild.

Still, PDT as it's currently used is not without its problems. Argon laser light cannot pass through more than about 1 centimeter of tissue (a little more than one-third of an inch), which means it's not useful against deeper tumors. And the photosensitizing agents used today can leave people very sensitive to light, causing sunburn-like reactions after only very brief sun exposure. This can greatly limit the patient's activities until the body gets rid of the drug, which often takes weeks. PDT is sometimes used to treat cancers and pre-cancers of the swallowing tube (esophagus), and certain kinds of lung cancer that can be reached with endoscopes. PDT is being studied for use in other cancers, such as those of the brain and prostate.

2. Lasers instruments in plastic surgery

Ablative Lasers

Lasers that nonspecifically destroy tissue can be used to remove skin lesions or layers of skin, usually with minimal blood loss because the dermal vessels are coagulated as the tissue is vaporized. CO2 laser light is absorbed by intracellular water, which vaporizes tissue as the water turns to steam.

Vascular Lesion Lasers

Oxyhemoglobin absorbs green and yellow light, spawning a variety of lasers appropriate for treating dermal vessels Historically the argon (blue/green) laser was the first clinically useful laser, but yellow light has become the preferred color (oxyhemoglobin absorption peaks at 577 nm yellow light), with the pulsed yellow dye laser (intentionally adjusted to 585nm and 595 nm for greater dermal penetration) the most popular type. The high-energy/short-duration pulse causes vascular disruption as the blood rapidly heats up and expands. The KTP laser (532 nm; green light) also targets oxyhemoglobin, but the pulses are much longer in duration, and tend to coagulate rather than disrupt vessels.

Pigmented Lesion Lasers

Pigmented lesion lasers target melanin. Congenital nevi will also lighten with laser therapy, but this use of laser is controversial. Although it is unlikely that laser will increase the risk of malignant transformation, it may delay the diagnosis of a changing nevus by masking the color change associated with a melanoma.

Photodynamic Therapy

The use of light-activated drugs to treat acne and other skin conditions currently is best represented by Levulan. The compound is metabolized by sebaceous glands into porphyrins. The acne bacteria itself also produces porphyrin, and the use of blue, green, or red light stimulates the production of oxygen free radicals that destroy the bacteria and suppress sebaceous gland activity.

Non-laser Phototherapy

Intense pulsed light is not actually laser light. Xenon flashlamps generate multiwavelength noncoherent light that is partially modulated by a series of filters. Intense pulsed light is used for sun-related pigmentary changes, telangiectasias, and for hair removal.

TABLE.1. LASERS WITH PLASTIC SURGERY APPLICATIONS

Name		Wavelength (nm)	Target chromophore
Solid	Ruby	694	Melanin, tattoo pigment
	Neodymium:YAG	1064	Pigment
	KTP (potassium titanyl phosphate)	532	Oxyhemoglobin, melanin
	Erbium:YAG	2940	Water
	Diode	800	Melanin (oxyhemoglobin)
	Alexandrite	755	Melanin, tattoo pigment
	Copper vapor	578	Oxyhemoglobin
Liquid	Yellow dye	585	Oxyhemoglobin
	Yellow dye	595	Oxyhemoglobin
	Green dye	510	Melanin
Gas	Argon	488, 514	Oxyhemoglobin, melanin
	Helium:Neon	633	
	Carbon dioxide	10,600	Water
	Excimer	Ultraviolet	Breaks chemical bonds

TABLE.2. CLINICALLY USEFUL LASERS AND OTHER PHOTOTHERAPY DEVICES

Vascular lesions	Yellow dye
	KTP
	Nd:YAG
	Copper vapor
	Intense pulsed light
Skin resurfacing	Carbon dioxide
	Erbium:YAG
	Radiofrequency
Benign lesions, pigmented	Intense pulsed light
	Diode
	Ruby
Benign lesions, cutaneous	Carbon dioxide
Hair removal	Alexandrite
	Diode
	Neodymium:YAG
	Ruby
	Intense pulsed light
Tattoo removal	Ruby
	Alexandrite
	Neodymium:YAG

3. Laser in Surgery for Brain Tumors

Surgery is the primary treatment for brain tumors that can be removed without causing severe damage. Many benign (non-cancerous) tumors are treated only by surgery. Most malignant (cancerous) tumors, however, require treatment in addition to the surgery, such as radiation therapy and/or chemotherapy. The goals of surgical treatment for brain tumors are multiple and may include one or more of the following:

- Confirm diagnosis by obtaining tissue that is examined under a microscope.
- Remove all or as much of the tumor as possible.
- Reduce symptoms and improve quality of life by relieving intracranial pressure caused by the cancer.
- Provide access for implantation of internal chemotherapy or radiation.
- Provide access for delivering intra-surgical treatments, including hypertherapy or laser surgery.

Fig.2. Laser for Brain Tumor Surgery

Imaging and Monitoring Techniques (Brain Mapping)

Doctors use a variety of techniques to determine what a brain tumor looks like both before and during surgery. Specialized images can be generated that shows what functions the brain tissue near the cancer is responsible for. Generating images both before and during surgery can increase the likelihood that extensive tumor removal can be achieved while avoiding these critical areas.

Before surgery, the location of the brain tumor in relation to other structures and blood vessels must be determined as precisely as possible. To achieve this, a variety of tests are performed. These may include:

- Computerized tomography (CT),
- Magnetic resonance imaging (MRI),
- Positron emission tomography (PET), and
- Angiography (to map blood vessels).

Using the information obtained from these tests, the surgeon can plan and even rehearse the operation in order to obtain optimal results. Evaluation of outcomes in elderly patients who had undergone surgery for brain tumors indicates that those who underwent preoperative MRI experienced better

outcomes than those patients who were not evaluated with MRI before surgery.

Techniques for brain mapping include:

- Direct cortical stimulation,
- Evoked potentials,
- Functional MRI,
- Intraoperative ultrasound imaging, and
- Microsurgery.

Direct cortical stimulation: In direct cortical stimulation, a probe passes a tiny electrical current into the brain and delicately stimulates a specific area. The result is a response from the body, such as a visible movement of the corresponding body part. This technique may be employed during surgery to help identify important functional areas..

Evoked potentials: The electrical response of the brain can be measured by stimulating the brain and measuring the resulting activity, or evoked potentials, on brain scanning equipment. Evoked potentials may be used to map and continuously monitor areas of the brain during surgery.

Functional MRI: MRI is a high-speed imaging device that generates images of the tumor's use of oxygen. This helps distinguish between active, normal brain, and non-active tumor or dead tissue (necrosis). Functional MRI can be an alternative to direct cortical stimulation.

Intraoperative ultrasound imaging: The use of ultrasound during surgery can help determine the depth of the tumor and its diameter. Ultrasound works by sending ultrasonic wave pulses into the brain, which then reflect back to a device. A computer measures the amount of time it takes for the "echoes" to return, and the results are displayed as a TV image. Surgeons can monitor their movements to verify positioning and results during surgery. The waves can also reflect motion such as blood flow. Ultrasound can make it easier for the surgeon to locate the margins of the tumor so that more extensive tumor removal can be achieved. It helps distinguish between tumor, necrosis (dead tumor cells), cysts, edema, and normal brain. Because ultrasound does not readily penetrate bone, it cannot be used preoperatively.

Microsurgery: Microsurgery involves the use of a high-powered microscope during surgery, which allows the surgeon to obtain a magnified view of the surgical field. Microsurgery is widely used for brain tumor surgery.

Surgical Techniques

Many different surgical techniques are utilized in the treatment of brain tumors, particularly in large medical centers that treat a significant number of patients. The technique utilized for a particular patient depends on the type of tumor and its location as well as the preference of the surgeon. The surgical techniques most commonly employed in the treatment of brain tumors include:

- Stereotactic surgery,
- Embolization ,
- Endoscopy,
- Laser surgery,
- Photodynamic laser surgery, and
- Ultrasonic aspiration.

Stereotactic surgery: The use of computers to create a three-dimensional image is called stereotaxy. The purpose of this technique is to provide precise information about the location of a tumor and its position relative to the many structures in the brain. Stereotaxy can be used by the surgeon to map out the surgical procedure beforehand so that the neurosurgeon can "rehearse" the procedure or to allow the radiation specialist to plan radiation therapy.

While conventional X-ray pictures depict tumors in two dimensions, stereotaxy provides the third dimension—depth—by obtaining readings in both left to right and front to rear directions, and then using a computer to analyze the information. It is the third dimension that allows the surgeon to accurately insert the needle for biopsy, the laser beam for vaporization, the scalpel for cutting, or the suction device for aspiration.

Stereotactic surgical techniques are used to perform biopsies, remove tumors, implant radiation pellets or other local treatments, or to provide a navigational system during surgery (frameless stereotaxy). These techniques are particularly useful for reaching a tumor located deep within the brain, such as the brain stem or thalamus. Stereotaxy can also help limit the extent of surgery. Some stereotactic systems can project images of the surgery as it is being performed ("real-time" imaging). Stereotaxy is performed either with or without a head frame.

Embolization: Embolization is used to reduce the amount of blood supply to a tumor by blocking the flow of blood in selected arteries. This procedure is conducted prior to surgery. Results from an arteriography, which is an X-ray taken after radiolabeled dye has been injected into the circulatory system, help determine whether embolization is necessary and which blood vessel or vessels may need to be blocked. Surgery follows as soon as possible to avoid re-growth of blood vessels. This technique might be used with vascular tumors such as meningiomas, meningeal hemangiopericytomas, and glomus jugulare tumors.

Endoscopy: Endoscopes are long, narrow, flexible lighted tubes that are inserted into the surgical area. They provide the surgeon with light and visual access. Preoperative scans help determine the location of tumors and enable the surgeon to plan surgery using relatively small openings. These small openings (sometimes called keyhole approaches) make it difficult for the surgeon to see. The endoscope helps solve that problem. The neuro-endoscope is particularly useful for surgery that involves correcting a malfunctioning shunt, removing scar tissue blocking a shunt, or removing intra-ventricular tumors. It can also be useful for removing brain cysts.

Laser surgery: Using a laser during brain surgery is a relatively routine practice. The aim of laser surgery is to direct the laser beams at the cancer and destroy it with heat. Because the light beams cannot penetrate bone, the laser can be used only during surgery. Lasers are used in addition to, or in place of, a scalpel. Lasers are capable of immense heat and power when focused at close range. Lasers destroy tumor cells by vaporizing them. Stereotactic, or computer-assisted techniques, are frequently used to direct the laser. Lasers are chiefly used in the treatment of tumors that have invaded the skull base or are deep within the brain, with hard tumors that cannot be removed by suction, or with tumors that break apart easily.

Photodynamic laser surgery: A laser is also used in photodynamic therapy. Photodynamic therapy combines a drug that increases a tissue's sensitivity to light and laser surgery. Prior to surgery, the photosensitizing drug is injected into a vein or artery. It travels through the blood system to the tumor, accumulating in the cells of the tumor. The patient is then taken to surgery for removal of the tumor. During the operation, the treated tumor cells appear fluorescent. The physician aims a laser at the tumor cells, activating the drug. The activated drug then kills the tumor cells.

Ultrasonic aspiration: Ultrasonic aspiration uses ultrasonic sound waves to fragment and break the tumor into small pieces, which are then aspirated, or suctioned out. This technique causes fewer disturbances to adjacent tissue than other types of suction devices because it causes less heat and destruction of normal tissue. This is particularly helpful with tumors that would be difficult to remove with cautery and suction because of their firmness and location. As with the laser, the use of ultrasound has permitted the removal of tumors that would otherwise have been inoperable.

III. CONCLUSION

Lasers are more precise than standard surgical tools (scalpels), so they do less damage to normal tissues. As a result, patients usually have less pain, bleeding, swelling, and scarring. With laser therapy, operations are usually shorter. In fact, laser based treatment can often be done on an outpatient basis. It takes less time for patients to heal after laser surgery, and they are less likely to get infections. Patients should consult with their health care provider about whether laser therapy is appropriate for them. Laser based instruments are widely used in medical applications. They are used in treatment of cancer, removal of tumors of vocal cords, brain surgery, plastic surgery, gynecology and oncology. Lasers can focus very accurately on tiny areas; they can also be used for very precise surgical work.

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