Innovative: International Multi-disciplinary Journal of Applied Technology
(ISSN 2995-486X) VOLUME 02 ISSUE 09, 2024

Uses of Laser in Surgery: a Comprehensive Review

Nisreen Hadi Attia
University of Fallujah, College of Applied Sciences Department of Medical Physics

hur hussein hamza
Wasit University, Faculty of Science, Department of Medical Physics

Alaa Wasfi Sahi
University of Baghdad, Department of Medical Physics

Ahmad Bassem mohsen
University of Fallujah, College of Applied Sciences Department of Medical Physics

1. Introduction

Minimally invasive surgical techniques have gained persistent interest in the past few years due to their advantages, such as minimal trauma to healthy tissues, the lesser duration of hospitalization, quick recovery, and lesser wound-related complications. Various techniques have been based on the utilization of energy, such as electrical energy, radio frequency energy, and laser energy. Lasers have been utilized in the medical field for over three decades. It has tremendous potential for performing a multitude of functions, starting from diagnosis to ablation and photocoagulation.

Several tissues, such as nails, gums, pancreas, and prostate, are tried to be treated with the help of laser energy. Many surgical procedures have been developed based on the laser. The facilities of the laser surgery techniques are still limited to concern hospitals and clinics due to the requirement of modern expensive surgical equipment. The basic understanding of laser technology is crucial in accurate utilization; it includes a working understanding of different devices, dealing with different tissues, and preventing mishaps and minor complications.

The laser is the acronym of Light Amplification by Stimulated Emission of Radiation. It can be classified into different types based on the active medium employed to generate the laser light. Based on the type of active medium, lasers have been categorized into four major types: solid-state lasers, gas lasers, dye lasers, and semiconductor lasers. Lasers can also be classified as continuous-wave and pulsed lasers based on output energy. The principle underlying the function of lasers is the interaction of excited atoms. When an electron supplies external energy, it will jump from a lower-energy state to a higher-energy state. [1][2]

1.1. Overview of Laser Technology

In recent years, lasers have been incorporated widely in the health field. Adjustment of laser parameters led to extensive uses in surgery. Advantages of laser applications include: (1) Minimal blood loss. (2) Minimal tissue destruction, resulting in faster recovery. (3) Lower complication rates, including infections. This review describes the basic concept and principles of lasers, mechanisms of interaction with tissues, and notable surgical applications. Traditional surgical modalities include manually operated tools or devices such as scalpels, scissors, hot wires, knives, and electrosurgical instruments. Mechanical and thermal effects achieve cutting and cauterizing, respectively. Except for some cases, these modalities create more debris and damage larger tissue surrounding the target, resulting in complications. In the last decades of the 20th century, adjustment of laser parameters expanded applications in surgery.

A laser is a light source emitting monochromatic, coherent, and parallel beams. The term laser is an acronym of Light Amplification by Stimulated Emission of Radiation. The 'laser' was invented by Maiman in 1960. It was originally a ruby solid-state laser producing red light of 694 nm. Lasers consist of gain media, a resonator cavity provided with two mirrors, and energy pumps. Gain media are gas, solid state, or liquid dye mixtures. Coherent light is generated in the gain medium by stimulated emission under excitation by light (flashlamp, laser diode) or electric spark (He-Ne). Photons produced travel in a parallel direction and amplify other coherent light rays passing through the medium. Amplified photons exit from the cavity through partially reflecting mirrors at a specific wavelength depending on the medium. Most lasers are closed-loop systems. Coherent light generates high energy density, which can be focused on a very small area (10-5 to 10-7 cm). The high intensity raises interactions with atoms in target tissues in near homogeneous manners. Hence, lasers are widely applied in ablation, coagulation, cutting, disinfecting, and wound healing.

Mechanisms of laser-tissue interactions depend on wavelength, focusing, energy densities, and temporal features. Well-calibrated lasers can have selective and originally intended effects. Laser systems complemented by fiber optics can be equipped inside endoscopes to reach distal target sites. Interaction and possible injuries increase as the beam gets more focused and dense. These also increase with longer pulse widths (milliseconds). Selective photothermolysis is the most commonly used mechanism. Theoretically, electromagnetic absorption is followed by fast thermal diffusion, which is about a thousand times faster than electron relaxation to heat crystals. The cooling becomes slower as the laser fluence rises above the desired level. [3][4]

2. Types of Lasers in Surgery

The laser is a source of electromagnetic radiation with a single wavelength. The use of lasers for therapeutic applications began in the 1960s, initially for incision and ablation of human tissues, and subsequently in endoscopic applications. There are various laser systems now used in surgical or therapeutic applications on the human body. Among surgical lasers, carbon dioxide (CO2), neodymium yttrium aluminum garnet (Nd:YAG), potassium-titanyl-phosphate (KTP), argon, and holmium yttrium aluminum garnet (Ho:YAG) lasers are the most widely used.

CO2 laser systems were the first to be used in surgical applications and are still the most extensively utilized. CO2 laser radiation is in the infrared region (10.6 μm) of the electromagnetic spectrum. Almost all tissue absorbs laser radiation at this specific wavelength because of the presence of water, which makes the CO2 laser system ideally suited for thermal tissue welding/disruption. CO2 lasers are used in various surgical disciplines including dental, orthopedic, urology, ophthalmology, dermatology, general surgery, gynecology, ENT, thoracic, and even transplantation. Contemporary

CO2 laser systems generate a continuous wave (CW) or super pulse beam to produce a thermally influenced zone in the tissue. CO2 lasers can be applied with a diagnostic detachable fiber or a delivery system that permits targeting the optical focus on a tissue.

In recent years, the use of CO2 laser in endoscopic surgery has increased dramatically, especially for gastrointestinal malignancies, gynecologic, laryngeal, and pulmonary diseases. Lasers are routinely employed in other surgical applications such as the correction of myopia, malignancies of neck and other sites, skin wrinkling, tattoo removal, treatment of vascular anomalies, and other conditions. More recently introduced systems, including holmium lasers and the newly developed diode laser, exhibit distinct advantages in the form of a small delivery system and manipulability with flexible endoscopes. This system also seems to provide more efficient hemostasis and tissue ablation, but it is still being comparatively evaluated with CO2 lasers. [5][6][7]

2.1. Carbon Dioxide (CO2) Lasers

In the realm of surgical procedures that have radically transformed the practice of medicine, laser wavelengths originating from closely spaced contemporary lasers, such as the carbon dioxide (CO2) laser, appear to build upon traditional ideas. Since their inception and expansion into surgical use in the mid-1980s, CO2 lasers have repeatedly been wielded and claimed wondrous powers. However, from the very beginning, the devices and the tissues worked upon have appeared unwieldy, difficult, and unpredictable. In fact, across conventional and laser surgery alike, there exist the tissue and the surgeon, sometimes an intermediate device or agent, and more often than not, between them a direct energy transfer, here in the form of photons.

Further examination of such reported and observable difficulties reveals a most interesting and curiously common fundamental design flaw – that is, a mismatch. In general, a mismatch occurs when one quantity does not align, or is not compatible with another. In this case, the mismatch is between the biological target of laser surgery and the laser used, specifically the wavelength of the CO2 laser used. This realization appears most crucial in obtaining scientifically credible, reproducible results with CO2 lasers in surgical practice. However, it has been and continues to be a major obstacle to the widespread application and appropriate appropriation of such devices.

In laser surgery using continuous wave CO2 lasers, observable and perhaps reportable effects are limited to deeper, potentially hazardous, penetrative phenomena, in conjunction with tissue charring, heating, and/or destruction. In contrast, under such conditions, the most interested or rate controllable effects also sought after in conventional, non-laser surgery are at best incidental and limited. Namely, predictable, precise, shallow, non-destructive effects wherein tissue remains apparently intact are possible upon treatment with very short pulse duration irradiation. Careful adjustment of parameters allows effects at or very near the surface to be created nearly independently of tissue properties and in relation to the armada of other highly variable component inputs within the realm of surgery. [8][9]

3. Advantages of Laser Surgery

In the last three decades, significant advancements in laser technology have been made, benefiting various fields. Among these fields, medicine has experienced widespread advancements and applications of lasers, particularly in the surgical domain. Laser surgery or laser ablation is a contemporary surgical method that employs lasers to excise or ablate tissue. A laser is a device that emits a coherent, highly focused beam of monochromatic light. Laser surgery has various advantages over traditional surgical methods, including precision and accuracy, a bloodless field, minimal postoperative pain, and a shorter recovery time. In this paper, the basic principles of laser surgery, the different types of lasers used in surgery, their applications in surgical specialties, and the advantages of laser surgery are reviewed.

Cutting or tissue excision is performed by the absorption of laser energy by tissue chromophores, causing thermal elevation of tissue temperature and vaporization of tissue. Laser vaporization is a low-energy laser-tissue interaction mode in which tissue exfoliation is accomplished by the mechanical effects of rapidly evaporating water vapor bubbles. Diode lasers can be additionally used in photocoagulation, a laser-tissue interaction that produces hemostatic tissue alteration by the absorption of laser energy by hemoglobin to thermally denature collagen fibers. Lasers have been employed for the incisional surgical procedure like corneal flap creation in LASIK to excise the corneal tissue.

Over the past few decades, lasers have been extensively used for soft tissue surgery in various medical fields, including laser pharyngoplasty, laser gingivectomy, laser frenectomy, laser treatment of recurrent aphthous ulcer, laser excision of pyogenic granuloma, and laser surgery for leukoedema. Conventional surgical excision generally results in a reflexive wound healing response, which can lead to undesired complications like scar formation. In contrast, laser ablation employs photothermal interaction that selectively removes the tissue while limiting wider zone tissue alteration. Due to rapid lateral diffusion of temperature from the focal spot, tissue injury is confined to a microscopic zone. Lasers improve healing with favorable re-epithelialization and reduced inflammatory response.

The precision and accuracy of laser surgery provide several advantages. The focused nature of lasers allows easy access to tissue structures or organs that are difficult to reach. Lasers produce controlled tissue vaporization, which prevents lateral tissue alteration and can avoid damage to adjacent sensitive structures. The precision of laser surgery also permits excision in a layered manner, sparing deeper structures. Avoiding deep tissue alteration may help in preserving functions, as seen when using CO2 lasers during the excision of vocal fold lesions, where the preservation of the deeper lamina propria provides good vocal outcomes. [10][11]

3.1. Precision and Accuracy

The development of laser surgery has come to the forefront in the medical field in recent times. Lasers have a number of therapeutic benefits because of their unique capacity to target small areas or depths of tissue while at the same time limiting damage to the surrounding healthy tissue. The unique properties of laser light, including coherence, monochromaticity, directionality, and high intensity, have made its use in surgical or therapeutic procedures effective and advantageous. In surgery, lasers assist in cutting, removing, destroying, or ablating tissue.

When compared to scalpel surgery, laser surgery offers a number of benefits, some of which are listed below. A laser is safer since the cut made by a laser is less likely to bleed. This is due to the laser's capacity to cauterize vessels, which prevents blood from escaping the body immediately after they are caught in the laser beam. Bleeding from surrounding tissues is also reduced, which keeps the surgical site clean and allows the surgeon to work more effectively. Laser surgery is more effective because it can be done more quickly and precisely. Additionally, surrounding healthy tissues are safe because the laser is just activated when it is really required. Health complications brought on by surgical interventions are diminished because there is less damage to surrounding tissues.

One serious complication following routine surgery is infection. Laser surgery lowers the risk of infection because lasers sterilize the tissues as they slice through them. The heat produced during the surgical procedure also aids in this. Because the laser is effective and precise, less anesthesia is required. This makes laser surgery a safer option, particularly for elderly or ailing patients. Local laser treatment can also be performed on the patient under local anesthesia, which eliminates the risks associated with general anesthesia. Scarring and swelling are also diminished or entirely avoided. In heart surgery, for instance, as opposed to scalpels, lasers are more likely to result in fewer heart tissue scars. The use of lasers in removing tissue also aids in leaving surfaces smooth or with a polished appearance. Lasers can be employed to alter or enhance the surfaces for the best functional capability of several medical devices.

The procedures are quicker and more difficult to screw up than traditional surgery, which allows for more complicated adjustments. Lasers can aid with vision correction, teeth reshaping, bone hardening, plaque deterioration, and increasing the strength of drug delivery for the treatment of colitis ulcerative, wherein they are helpful for tissue repair. There is also market demand for laser-assisted surgeries, which can directly result in marketing opportunities in the healthcare and medical device/hardware industries. [12][13]

4. Common Surgical Procedures Using Laser Technology

Over the years, lasers have gained wide acceptance in various surgical specialties. These procedures have a greater niche in soft tissue surgeries. Lasers are photonic devices that produce a monochromatic coherent light beam through a process known as stimulated emission of radiation. Lasers can be classified based on their properties, including wavelength, energy density, and output power. Lasers can be used for their hemostatic capabilities, usefulness in cutting tissues, and less collateral damage to the surrounding tissues (compared to the traditional cutting tools).

Lasers have found their place in surgical theaters of various specialties, including dermatology, urology, ENT, ophthalmology, gynecology, gastroenterology, neurosurgeons, and orthopedic surgeries. Among other surgical instruments, laser use in surgery has advantages and disadvantages. The first laser was invented by Dr. Theodore H. Maiman in 1960 using ruby as the medium. The laser is an acronym for Light Amplification by Stimulated Emission of Radiation and saw its first application in surgery in the 1960s. In surgery, lasers can be used for cutting, vaporization, photocoagulation, sclerotherapy, and barotrauma.

Laser eye surgery, also known as laser vision correction or refractive surgery, is a common surgical procedure that uses laser technology to reshape the cornea of the eye and improve vision. Millions of people around the world have undergone laser eye surgery to reduce their dependence on glasses or contact lenses. This procedure is performed by an ophthalmologist, a doctor specializing in eye care and eye surgery, using specialized equipment. Laser eye surgery can treat a range of vision problems, including myopia (nearsightedness), hyperopia (farsightedness), and astigmatism.

Before the surgery, a thorough examination is conducted to determine the patient's suitability for the procedure. This includes measuring the shape and thickness of the cornea, assessing the overall health of the eye, and determining the patient's prescription. During the surgery, a computer-controlled laser is used to remove a thin layer of tissue from the surface of the cornea (in photorefractive keratectomy (PRK)) or inside the cornea (in laser in-situ keratomileusis (LASIK)). This reshapes the cornea and allows light to focus correctly on the retina. The procedure is painless and takes only a few minutes for both eyes. After the surgery, the patient is monitored for a short time before being allowed to go home. Recovery time varies, but most people notice an improvement in their vision within a day or two.

Laser eye surgery is a safe and effective option for treating refractive errors. Nevertheless, as with any surgical procedure, there are potential risks and complications. These can include dry eyes, glare or halos around lights at night, undercorrection or overcorrection of the vision, and, in rare cases, loss of vision. It is essential for patients to discuss these risks thoroughly with their surgeon before undergoing the procedure. [14][15]

4.1. Laser Eye Surgery

The laser technology discovered in 1960 by Theodore Maiman paved the way for applications of laser beams in surgery. The laser beam is a narrow, intense beam of light. The word laser is an acronym for Light Amplification by Stimulated Emission of Radiation. A laser can produce a beam of light that is highly focused and has a high intensity. The intense beam can either cut or vaporize tissue. The first laser was a ruby laser, and the first surgical application of the laser was done on the eye. The ruby laser was used to create tiny holes in the retina to treat retinal detachment. Since then, a number of lasers have been developed. The lasers are classified into various categories based on the tissue, chromophore, or color of the laser. Common solid-state lasers used in surgery are Nd: YAG (neodymium: yttrium aluminum garnet) laser, pulsed dye laser, CO2 laser, Erbium YAG laser, etc. Lasers are used in a variety of surgical procedures due to the capabilities of the laser beams to cut tissue, vaporize tissue, coagulate blood vessels, seal tissues, destruct tumors, modify tissue, etc. Various surgical procedures using lasers are discussed in this chapter. Laser surgery is a growing field, and more applications of lasers are likely to be found in the future.

Laser eye surgery can correct vision problems. Laser eye surgery uses laser technology to reshape the cornea in order to focus light more effectively on the retina. The reshaping of the cornea corrects vision problems such as nearsightedness (myopia), farsightedness (hyperopia), and astigmatism. The procedure requires the surgeon to use the laser beam to remove corneal tissue. Initially, high-energy ultraviolet light excimer laser was used for laser eye surgery. Nowadays, femtosecond laser (IntraLase) is used for creating a corneal flap during LASIK. The femtosecond laser has precision, thus making the corneal cut very even. The slow conduction of this laser also reduces the chances of thermal damage. This laser generates a laser beam in the infrared wavelength. A solid neodymium with yttrium aluminum garnet (Nd: YAG) crystal is used in the femtosecond laser. Recently, an anterior segment optical coherence tomography (AS-OCT) has been approved by the FDA, which can also provide real-time imaging of the corneal flap during laser eye surgery. The laser eye surgery can be performed on several types of eye problems. A wide range of LASIK procedures are also available depending on the type of eye problem. [16][10]

5. Emerging Trends and Future Directions

While laser technology has certainly enhanced surgical capabilities and improved surgical outcomes, researchers and practitioners remain committed to continued improvement. One avenue for future development is simply increasing the availability of these instruments. Above and beyond the traditional handheld or mounted laser systems, there are quite a few data out there regarding the effectiveness of robotic-assisted laser surgery.

Since the early 2000s, the field of robotic surgery has advanced quite rapidly. In addition to the da Vinci surgical system, which has become an industry standard in many urological and gynecological surgeries, many medical device companies have created robotic systems for cardiac, orthopedic, and head and neck surgeries. Some companies are even currently producing surgical robots intended for hospital use that can be controlled by surgeons working remotely, utilizing high-definition robotic vision and articulated scopes to perform complex surgical tasks without being physically present.

The newest frontier in robotic surgery is its combination with laser treatment. Robotic assistance for CO2 laser treatment is gaining in popularity, as the high magnification and excellent view of soft tissue offered by many robotic systems are perfect for using a laser for excisional procedures. Furthermore, the opportunity for additional thermal control provided by a CO2 laser and robotic assistance strongly aligns with the interest in human clinical studies utilizing CO2 lasers in combination with surgical robots.

At the same time, laser systems are becoming more readily available to medical practitioners as their costs decrease. A broader range of uses for laser technology is certain to emerge as knowledge and proficiency regarding its use grows among surgeons. [17][18]

5.1. Robotic-Assisted Laser Surgery

Robotic-assisted laser surgery is a cutting-edge field that combines the precision of lasers with the dexterity of robotic systems. The goal is to enhance surgical outcomes while minimizing risks and downtime. With the increase in micro-procedures and the advent of new laser systems and robotic systems, there is a high push towards fusing these two technologies. Robotic laser surgery is still in development because of technical challenges; however, so far, early results are promising.

The challenge in robotic laser surgery is to provide the necessary tool motion while allowing the laser beam to reach the tissue without obstruction. For rigid endoscopic surgical lasers, the laser beam must be transmitted to the tissue despite the surgical tool motion and surgeon movement. This is complicated by the requirement of keeping the laser beam stationary in relation to the surgical site. Given this background, systems that have successfully been implemented will be described.

Laser-based systems for ablating tissue with limited tool motion (e.g., robotic surgical staplers, cutters, and needle drivers) have been developed. The simpler designs are based on a fiber optic laser mounted to the tool and illuminating the tissue from above so that the laser does not obstruct the tool motion. Tissues can be vaporized while maintaining the surgical stapler (LS-1) or needle driver (LS-2) positions safe for suturing.

Providing tool guidance while keeping the laser stationary is more complex. In one approach, a single robot mounts a robotic laser that continuously follows the tool when it moves in pitch (rotation around the horizontal axis). The robot can guide the laser during cut initiation and assist with margins truncation. The robotic guidance is early in development, and the standard delamination suture approach was not tested. Such a system would find the most applicability for potentially the most critical coverage in robotic laser surgery during the initial cut. The immediate controller cannot keep up with high-motion speeds and also takes time to compute the adjustments; therefore, there are surgical risks when using without locked positions (one joint fixed)—the end-tool angle controls attachment to the leaves or tissues could be lost (especially if only using one robot to track the laser). Overall, this system realizes a complex optomechanical assembly that successfully provides a solution for the most changed trajectory in laser surgery but with related downsides.

Other systems mounted two robots (one on the laser and another tracking the endoscope/tool) so to provide perturbation signals to a complex controller that analyzes states and computes adjustments to maintain the laser on the tool. This is less complex mechanically but needs to analyze delays coming from both technologies to ensure real-time adjustment. Implementations of laser tracking by flexural mirrors or computer vision also exist to reflexively maintain the laser on the tool, being applicable to tools from different manufacturers. These additional devices, nonetheless, greatly increase the expense of the procedure and its volume and complexity. [19][20]

6. Safety Considerations and Risk Factors

The use of lasers in medical applications has become a vital extension for innovation in technologies, diagnosis, and treatment in harmony with safety. The recent years have witnessed the advent of technological improvements in lasers regarding them as new medical devices for treatment in surgical procedures. Studies have revealed the efficacy of laser technology in terms of successful outcome and treatment time. Nevertheless, the senior surgeons have been subjected to an expectation regarding the safety of laser technology regarding health hazards or side effects. With the introduction of any new technology, in-depth investigations are required regarding side effects and safety considerations to avoid any life-threatening complications. Although the long-term health considerations are quite difficult to predict, at least proof for no immediate adverse effects are awaited. In the long run, studies so far undertaken have mostly concentrated on the conduct of safety measures. Another aspect of the technology relates to the need for protection against the chance of accidents.

Most of the laser operations are carried out being in a direct line to the projection of the laser beam. The eye is especially susceptible to all cell types selected for laser treatment. The retinal pigment epithelium (RPE) cannot regenerate in higher animals, including man, after laser damage and would be eliminated as a target tissue for further laser applications. In treating the retina, there are especially high risks involved, since avoiding laser irradiation to the untreated tissue is generally not possible. In this area, there has been great effort to find drugs to protect against additional damage by subsequent laser exposure. In addition, there have been continuous investigations into safety limits regarding intensity, area structure, and pulse width of the beam applied. Early studies of laser safety employed in vitro models that were primarily concerned with injury thresholds under exposure to laser radiation. The advent of new technologies and unintended consequences pointed to the need for ongoing research into, and consideration of, general laser safety. Recent developments in laser application for reforming corneal surfaces and intra-ocular surgery have highlighted concern about exposure of photoreceptor, RPE, and retinal ganglion cells to potentially destructive laser interaction. Use of the laser in all medical procedures must reflect a balance between the need to mitigate iatrogenic risk against a responsibility to treat patients with the best available technology. [21][22]

6.1. Eye Protection during Laser Surgery

The use of lasers in surgical procedures has become increasingly popular due to their precision and efficiency. However, with the growing use of lasers in surgery, it is important to ensure that adequate safety measures are taken. One of the most important safety measures is to protect the eyes during laser surgery. Lasers can cause eye injuries both directly from viewing the beam and from reflected radiation. Therefore, eye protection is vital during laser procedures to prevent accidents and ensure safe treatment protocols.

Establishing a laser safety program is essential in institutions where lasers are used. Laser safety officers should be appointed to oversee the implementation of safety measures. These officers are responsible for regularly inspecting the area where lasers are used to ensure adequate safety measures are taken. If lasers are used on patients in a hospital or clinic, protective measures should be taken to prevent unnecessary exposure of personnel. Patients should also be protected during laser procedures. The type of protection required depends on the type of laser being used. For CO2 lasers, infrared-filtering goggles are necessary. For high-energy Nd:YAG lasers, protection from visible and infrared wavelengths is required. It is important to note that using goggles that do not fit well or fog up will not afford adequate protection, regardless of the level of filtering.

All personnel working with lasers should be trained on the potential hazards and safety procedures involved in using lasers. An educational program should cover the effects of lasers on different parts of the body, particularly the eyes, and the special protective measures that should be taken. [23][24]

7. Conclusion

In 1960, lasers were discovered and since then, lasers have become a boon to mankind, having applications in various fields. In medicine, lasers have proven to be a significant tool in sparing normal tissue and controlled tissue destruction. Lasers have found safe applications in diagnosis, treatment, and surgery. Newer technologies have come up in surgery with lasers such as envisaging, neo fencing, and biopsying using lasers. Laser surgery is a technique of focusing intense beams of specific wavelengths of light on a target area using a contact or non-contact hand-held delivery system. When compared to conventional surgery, lasers have many advantages such as an almost bloodless field, minimal cooling, and reduced industrial time, reduced risk of infection, quick recovery, and shorter hospitalization. Lasers have many uses in surgery which include carbon dioxide lasers, neodymium yttrium aluminum garnet lasers, argon lasers, diode lasers, and potassium titanyl phosphate lasers. While lasers have revolutionized medicine, knowledge of lasers in other surgical disciplines is very less. Laser beam technology is having various applications in medicine such as laser-induced breakdown spectroscopy, laser-induced fluorescence, Raman scattering, multi-photon absorption, and optical coherence tomography. Keeping this in mind, it is essential to know the uses of lasers in surgical procedures so that this pioneering technology can be incorporated into the management of patients and in surgical disciplines. Lasers have unprecedented uses in surgery with regard to major surgeries performed throughout life. It is the need of the hour to have the theoretical knowledge of lasers, their types, and uses so that these technologies can be incorporated into routine general surgical procedures.

The word "laser" was first coined in the 1960s. The full form of the word is "Light Amplification by Stimulated Emission of Radiation". Intended beams of concentrated radiant energy inside a cavity become "coherent", which means that the wave front is completely regular in time and space. When this focused beam has interaction with tissues, there are three possible processes through which the interaction occurs. They are elastic scattering, non-elastic scattering, and absorption. The lasers have been classified by different methods. The lasers have been further categorized. Applications of lasers in medicine include diagnostic and therapeutic applications. In recent years, lasers have proven to be significant instruments in computers, electronics, instrumentation, and a great boon to mankind. Lasers have entered the medical field in recent times. Lasers have been used in medicine for over 25 years. In medicine, lasers have proven to be a significant tool in sparing normal tissue and controlled tissue destruction. Lasers have found safe applications in diagnosis, treatment, and surgery. "Surgery" is a branch of medical science that involves the use of operative manual and instrumental techniques on a patient to treat a pathological condition. The term "surgery" is derived from the Greek word "Cheirourgika," which means "Handwork" or "Handiwork." Surgeries are classified into two types: conventional surgeries and endoscopic surgeries. Conventional surgeries are generally larger open surgeries involving extensive tissue manipulation. Endoscopic surgeries are smaller, light-guided surgeries with a video camera inbuilt into the scope. Retinopathy of prematurity and thoracoscopic sympathectomy for hyperhidrosis are examples of endoscopic surgeries. Newer technologies have come up in surgery with lasers, such as envisaging, neo fencing, and biopsying using lasers.

7.1. Summary of Key Points

Wavelength, optical output, pulse width, and energy fluency all play an essential role in the procedures. An ideal laser should also not damage the adjacent tissues for cosmetic procedures. All the lasers are used either in the continuous wave output or pulsed output mode. Based on the wavelength, the lasers are divided into various parts like excimer, holmium, yttrium, neodymium yttrium, erbium, etc. A variety of surgeries like surgical cutting, ablation of unwanted tissue, reshaping of cornea, skin resurfacing, dental caries removal, treating blocks in tears drainage system, kidney stones, gall bladder stone, liver tumor, prostate, and breast tumor, etc., are done with the help of lasers.

There is a tremendous improvement in both hard and soft tissue laser applications. Continuous surgical lasers, with emphasis on characteristically large effective spot sizes, low oscillation and focusing loss waveguide systems, also demonstrate enormous potential and utility in laser surgery. Amongst them, diode lasers, with their small size, reliability, versatility and unique CW operating characteristics offer exciting options for the expansion of laser applications in surgery, medicine and diagnosis.

Aside from a valid and meaningful overview of laser devices and principles of interventional management, the paper also provides a comprehensive review of current laser applications, which can be used by clinicians as a valuable reference for starting laser management in their everyday practice. Understanding the instrument, its effects on tissue, and handling of both the device and patient is essential for the development of safe and effective laser protocols. Continuous-wave Nd:YAG lasers with rigid fiber optics, greater than 1 mm in diameter, are now mainly used. Endoscopic Nd:YAG laser systems can be classified according to their mode of energy delivery on the basis of flexible quartz fibers, rigid quartz fibers, and free beam techniques. The choice of inflexible quartz guide or free beam technique depends on anatomy, pathology and surgical objectives.

Continuous-wave Nd:YAG laser systems operate at an output wavelength of 1.064 nm. At this wavelength, absorption by water is low. This allows the penetration of Nd:YAG lasers up to several millimeters in normal tissues and limits thermal damage at the tissue-laser interface. Carbon dioxide laser systems, on the other hand, operate at an output wavelength of 10.6 µm, and show greater absorption by both water and biological tissues. In addition to acting as an efficient heat source for physiopathological effects, CO_2 laser systems provide the capability of "superficial layering" in tissue, thus exhibiting a very large heat-affected zone.

References:

1. J. Zuo and X. Lin, "High-power laser systems," Laser & Photonics Reviews, 2022. [HTML]
2. X Wang, H Yu, P Li, Y Zhang, Y Wen, Y Qiu, Z Liu, et al., "Femtosecond laser-based processing methods and their applications in optical device manufacturing: A review," Optics & Laser Technology, Elsevier, 2021. [HTML]
3. S. Lanigan, "Therapeutic Applications: Dermatology—Selective Photothermolysis," Handbook of Laser Technology and Applications, 2021. [HTML]
4. M.G. Scopelliti, A. Hamidi-Sakr, S. Möller, "Selective photothermolysis in acne treatment: The impact of laser power," Journal of Cosmetic Dermatology, vol. 2024, Wiley Online Library. wiley.com
5. T. Noguchi, H. Hazama, T. Nishimura, Y. Morita, et al., "Enhancement of the safety and efficacy of colorectal endoscopic submucosal dissection using a CO2 laser," Lasers in Medical Science, vol. 2020, Springer, 2020. [HTML]
6. Y. Yi, L. Li, J. Li, X. Shu, H. Kang, C. Wang, et al., "Use of lasers in gastrointestinal endoscopy: a review of the literature," Lasers in Medical Science, vol. 2023, Springer, 2023. [HTML]
7. AS Schimberg, TM Klabbers, DJ Wellenstein, "Optimizing Settings for Office-Based Endoscopic CO2 Laser Surgery Using an Experimental Vocal Cord Model," The …, 2020, Wiley Online Library. wiley.com
8. M. Michalik, J. Szymańczyk, M. Stajnke, T. Ochrymiuk, et al., "Medical applications of diode lasers: pulsed versus continuous wave (cw) regime," Micromachines, 2021. mdpi.com
9. JH Lee, CE Seo, WJ Song, MJ Kwon, YS Park, JH Ko, "Combination treatment utilizing fractional ablative and continuous wave CO2 lasers for hypertrophic burn scars," Burns, Elsevier, 2021. [HTML]
10. C. Latz, T. Asshauer, C. Rathjen, and A. Mirshahi, "Femtosecond-laser assisted surgery of the eye: overview and impact of the low-energy concept," Micromachines, 2021. mdpi.com
11. T. Asshauer, C. Latz, A. Mirshahi, et al., "Femtosecond lasers for eye surgery applications: historical overview and modern low pulse energy concepts," Advanced Optical Technologies, vol. 2021, degruyter.com, 2021. degruyter.com

12. AP Apostolopoulos, S Angelis, M Kaitatzi, et al., "The facts and myths for the use of lasers in orthopedic surgery," in Therapeutic Effects of Medical Lasers, 2021, dl.begellhouse.com. [HTML]
13. V. C. Kantumuchu, "Lasers and their Industrial Applications," in Laser Surface Treatments for Tribological …, 2021, books.google.com. [HTML]
14. M. Ang, D. Gatinel, D.Z. Reinstein, E. Mertens, et al., "Refractive surgery beyond 2020," Eye, 2021, nature.com. nih.gov
15. J. Ortega-Usobiaga, C. Rocha-de-Lossada, et al., "Update on contraindications in laser corneal refractive surgery," Archivos de la Sociedad, vol. 2023, Elsevier, 2023. [HTML]
16. S. N. Joffe, "The 25th anniversary of laser vision correction in the United States," Clinical Ophthalmology, 2021. tandfonline.com
17. C. Daggett, A. Daggett, E. McBurney, and A. Murina, "Laser safety: the need for protocols," Cutis, 2020. mdedge.com
18. A. Manandhar, H. Zhu, E. Ozkan, and A. Shah, "Techno-economic impacts of using a laser-guided variable-rate spraying system to retrofit conventional constant-rate sprayers," Precision Agriculture, 2020. osu.edu
19. A. Schmidt, O. Mohareri, S. DiMaio, M.C. Yip, et al., "Tracking and mapping in medical computer vision: A review," Medical Image Analysis, vol. 2024, Elsevier, 2024. sciencedirect.com
20. P. A. York, R. Peña, D. Kent, and R. J. Wood, "Microrobotic laser steering for minimally invasive surgery," Science Robotics, 2021. [HTML]
21. SM George, F Lu, M Rao, LL Leach, et al., "The retinal pigment epithelium: Development, injury responses, and regenerative potential in mammalian and non-mammalian systems," in Progress in Retinal and Eye Research, Elsevier, 2021. nih.gov
22. A. Bird, "Role of retinal pigment epithelium in age-related macular disease: a systematic review," British Journal of Ophthalmology, 2021. [HTML]
23. F. Costantino, A. Falegnami, L. Fedele, M. Bernabei, et al., "New and emerging hazards for health and safety within digitalized manufacturing systems," Sustainability, 2021. mdpi.com
24. M. D. Soltani, E. Sarbazi, N. Bamiedakis, et al., "Safety analysis for laser-based optical wireless communications: A tutorial," arXiv preprint arXiv, 2021. [PDF]