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Lasers in medicine—a review

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Laser systems permit very high energy radiation of a single wavelength to be focused on a tiny spot, and have found application in many areas of engineering. They are also currently used in many branches of medicine. The fields reviewed here are ophthalmology, gynaecology, dermatology, otolaryngology, gastroenterology and physiotherapy. Lasers which are in wide use for medical applications include argon, YAG and carbon dioxide types. In many areas, lasers have been found to be more effective than conventional treatment methods with advantages including less blood loss, more accurate removal of unwanted tissue, shorter operating time and less postoperative pain. It is expected that the next decade will see the laser as an everyday tool in many more medical applications.

Introduction

The first laser (light amplification by stimulated emission of radiation) was demonstrated by Theodore Harold Maiman in May 1960 and was a ruby laser operating in weak, millisecond duration pulses at the red end of the visible spectrum. Lasers have since been developed with wavelengths from ultraviolet to far infrared. The time domain of operation ranges from picosecond pulses for close control to continuous operation, usually for high power requirements. Almost since its discovery, the laser has been investigated for possible use in medical applications [1].

All lasers produce radiation with a number of important properties. These include coherence (temporally and spatially in phase), monochromaticity and low divergence. For surgery, monochromaticity is particularly useful when tissue absorbs only certain wavelengths. Different colours of light have application to different coloured media; for example red material reflects red light but absorbs blue light. Collimation ensures complete delivery of the laser beam as well as focusing ability. Coherence is not known to be a useful property for surgery. Table 1 shows the wavelengths of the types of laser in common use.

Table 1. Wavelengths of lasers in common use

Laser	Wavelength (nm)	Region of spectrum
Helium–neon	632·8	Visible (red)
Ruby	694·3	Visible (red)
Argon	476·5–514·5	Visible (blue/green)
Nd:YAG	1060	Near-infrared
Carbon dioxide	10 600	Far-infrared

As the beam has very little divergence it has an approximately constant power density in space. Furthermore, laser beams have the advantage of a high concentration of energy per unit area ($J\ cm^{-2}$)[2]. Another property of particular laser beams is the beam spot which is defined as the circular area centred on the axis of the beam that contains 86% of the total power in the beam. The radius of this circle is the beam radius [3], and is typically 0·3–10·0 mm in lasers commonly used in medicine. Careful calibration of these laser properties allows small areas of unwanted tissue to be removed accurately.

All lasers contain three primary components, these being the active medium, the excitation mechanism and the feedback mechanism (figure 1). The generation of laser radiation takes place in the active, lasing medium which may be solid, liquid or gas. The properties of the medium determine the wavelength and other properties of the light produced. The atoms or molecules of the lasing medium are contained in a chamber initially in their ground state. These atoms or molecules are raised to a higher electronic or kinetic energy state by absorbing electrical, thermal or optical energy produced by the excitation mechanism. The molecule releases the energy as quanta of electromagnetic radiation which are reflected back into the chamber causing the stimulated emission of a second generation of quanta. The feedback mechanism consists of the reflectance mirror, which is 100% reflective, and the output coupler, which is a partially transmitting mirror. Because one surface is partially transmitting, the light amplified by stimulated emission of radiation can escape from one end of the chamber as a laser beam.

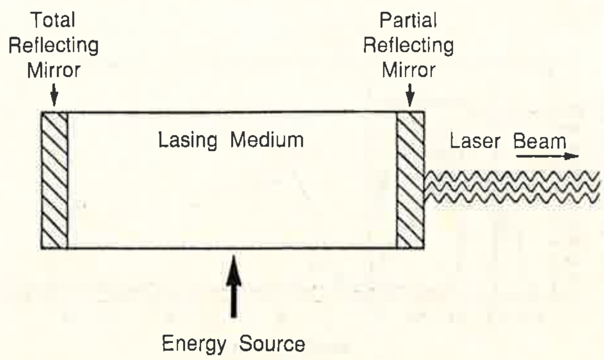

Figure 1. Primary components of a laser.

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The nature of the interaction of all laser light with material can be described in terms of reflection, transmission, scattering and absorption. In order for light to exert an effect on any human tissue it has to be absorbed [4]. When a laser is directed at soft tissue, the basic reaction is absorption of the radiation and thus destruction of tissue: the absorbed electromagnetic energy is instantaneously transformed into heat energy, which causes a sudden temperature rise in a small tissue volume. The process is called photocoagulation necrosis [5].

Laser energy absorption in the visible light range varies with the optical characteristics of the target. For example, red blood cells reflect the red light of the ruby laser (694·3 nm) but absorb the blue/green light of the argon laser (≃ 500 nm). Hence it is important that the operator knows the optical characteristics of the tissue as well as the properties of the laser. In the field of ophthalmology, much work has been done to determine the absorption characteristics of the various tissues of the eye [6]. Different lasers must be used according to the absorption of the particular wavelength by the region of interest. Figure 2 shows the absorption characteristics of haemoglobin, melanin and water relative to the wavelengths of the argon, Nd:YAG and carbon dioxide lasers. This shows the wavelengths which would be suitable for ablation of tissue containing these constituents.

A laser frequently used in medicine is the carbon dioxide laser. This emits radiation in the far infrared region with a wavelength of 10·6 μm. Its radiation is highly absorbed by water so is used to remove diseased soft tissue. However, there is no optical fibre available which transmits this wavelength. This limits the type of surgery possible because a handpiece containing mirrors carries the beam to the operative site. We discuss below the application of lasers to several specialties.

Ophthalmology

The use of lasers in ophthalmology is well established. It was the first surgical specialty to use such equipment, which was due to the natural link between the eye and optoelectronic research. Over the past three decades, ophthalmic applications of lasers have grown considerably, and now include outpatient treatment. Specific lasers are useful for specific tasks, for example glaucoma and diabetic retinopathy may both be treated with the argon laser while the Nd:YAG laser is used to treat 'dry eye'.

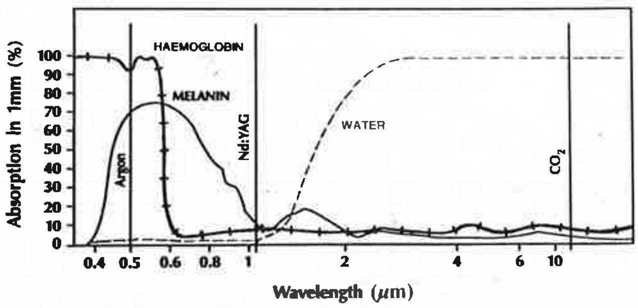

Figure 2. Absorption characteristics of tissue constituents.

The way in which optic tissue is modified by laser light is related to the ocular transmission characteristics of the wavelengths of the laser. Both the far infrared (1400 nm–1 mm) and far ultraviolet (200–295 nm) radiations will affect only the cornea at the front of the eye where they are absorbed. Near-ultraviolet (295–400 nm) will penetrate into the eye as far the lens, whereas the near-infrared (700–1400 nm) and all visible radiation (400–700 nm) will penetrate to the retina. While these characteristics give an indication of the suitability of different lasers for a particular application, they also show that different eye protection must be worn for different lasers.

Lasers are used in ophthalmology for both diagnosis and treatment. For example, holography may be used to study three-dimensional (3D) changes in the eye for diagnostic purposes. Holography is a technique which is similar in many ways to photography. In photography, an image is recorded which represents the 2D irradiance distribution of the object. In holography the object wave is recorded rather than an image. Both the amplitude and the phase of the wave are recorded so that when the recording is illuminated, the original object waveform is reconstructed even in the absence of the object. This is achieved by splitting a beam of monochromatic, coherent light from a laser and illuminating the object with one beam while the other falls on a photographic plate. The light illuminating the object is scattered onto the plate and the hologram is the interference pattern which forms in the photographic plate. When the hologram is illuminated with a beam similar to the original wave, one of the transmitted waves is a duplicate of the original object wave containing all the information about the object [7]. Hence large amounts of 3D information may be stored in a hologram. This 3D technique is particularly useful for examining the retinal changes indicative of glaucoma, a group of diseases of the eye produced by increased intraocular pressure which results in loss of the visual fields.

Safety considerations and low quality of image have prevented widespread clinical acceptance but holography may have many merits in this field. Holograms could easily be stored and a series of holograms made over a period of time permit sequential assessment. As more information becomes available about the safe use of lasers, and holography systems become more accurate, the use of this technique may become more widespread in the future.

When chronic simple glaucoma is diagnosed, the conventional initial treatment is beta-blockage [8]. The beta-blockers are applied topically to reduce the intraocular pressure by reducing the rate of production of aqueous humor. If this treatment fails, a laser may be used to make holes in the trabecular network tissue of the eye to allow drainage of the aqueous humor. Laser treatment was the goal of many researchers after Krasnov obtained temporary control using ultra-short ruby laser pulses [9]. Both argon and pulsed Nd:YAG lasers produce radiation which penetrates to the retina of the eye, and have been used with some success in this type of surgery.

There has also been interest shown in the role of laser trabeculoplasty in the primary treatment of chronic simple glaucoma. This interest is due to poor drug compliance, wide choice of drug and poorly defined dosage, variable response to drug treatment and frequent side-effects experienced when conventional treatment is used [10]. Laser trabeculoplasty is performed by spacing laser microburns around the trabecular meshwork to reduce the ring diameter of the meshwork. Reduction in intraocular pressure results. A small study has compared laser trabeculoplasty with medication therapy [11]. The study found no significant statistical differences between the success rates in the two groups but a larger trial is under way in the USA [8]. A pilot study has found that the new erbium:YAG laser (1·06 μm) may also be useful for this procedure with little thermal damage caused.

A second form of glaucoma is narrow-angle glaucoma. The traditional treatment for this has been surgical iridectomy, in which part of the iris is removed. In recent years a laser has been used to make a hole in the iris (iridotomy). This process has gained widespread acceptance as a superior treatment [12]. The argon laser and the Nd:YAG laser have been evaluated in this application. No clear conclusions can be drawn as to which is a better overall system, as the penetration depth of radiation from each system is generally the same [13]. The action of the argon laser is thermal and both burns and shrinks iris tissue. However, the colour of the eye affects the process. A blue iris does not absorb the light from the argon laser as well as a dark iris [4]. When the Nd:YAG laser is used, tissue disruption is caused by optical breakdown and a resulting shockwave is set up. Transparent as well as pigmented tissue can be cut, so the colour of the iris becomes irrelevant when the Nd:YAG laser is used. No comparison with conventional surgery has been found in the literature.

Diabetic retinopathy, a major cause of new blindness in adults in the UK, may also be treated using the laser. The disease occurs when new blood vessels grow over the surface of the retina and invade the vitreous humor. These new vessels obstruct the passage of light to the retinal rods and cones, severely reducing visual acuity. The argon–ion laser is used to destroy parts of the retina by photocoagulation, causing a decrease in the retinal demand for blood and so the growth subsides. In one study the beneficial effect of photocoagulation has been found to last for at least 10 years in 69% of patients [14]. This disease was previously untreatable. The argon laser has also been found to be effective in the treatment of other retinal diseases such as retinal tears, age-related macular degeneration and complications of retinal vein thrombosis [8].

One technique which uses a pulsed Nd:YAG laser is performed after a patient has had a cataract removed. Removal is followed by a new lens being inserted and held in place by membranes which may fog after about 2 years. To cure the fogging, a Nd:YAG laser is focused behind the membrane and the resulting shockwaves cause the formation of a hole in the membrane. It is interesting to note that the laser system used was originally designed for an army tank range finder.

A further use of the Nd:YAG laser is in the treatment of dry eye, a condition in which there are insufficient tears produced to hydrate the cornea. There are about 200 chemical constituents in tears, and different tears have different compositions. Tears produced by laughter, stress or to remove a foreign body from the eye are all quite different. Treating dry eye with false tears would be very complicated. The Nd:YAG laser is used to produce a membrane scar in the lacus lacrimalis (drain canal) to block the canal so that tears are used more efficiently.

Excimer lasers produce light in the ultraviolet region which is selectively absorbed by the cornea. Equipment is available which enables ophthalmologists to reshape the anterior corneal surface and hence correct refractive error. Initial tests have shown that an over-correction is initially obtained with normalization of the error occurring within 1 month. Long-term results are awaited [15].

The carbon dioxide laser is in the far-infrared region (10·6 μm) and is therefore absorbed in the cornea. It is not currently used clinically in ophthalmology in the UK. The argon laser is widely used by ophthalmologists while other lasers such as Nd:YAG and excimer lasers are being investigated. Much research has already been carried out to develop current uses of lasers in this field, and this is likely to continue.

Gynaecology

The laser has been used in gynaecology since the early 1970s and is now available in a large proportion of the gynaecology departments in the UK. The most widely used laser in this field is the CO_2 laser, because its radiation is strongly absorbed by the water in diseased tissue so the energy vaporizes or incizes the impacted tissue by heating. A particularly valuable property is that, when diseased tissue is destroyed, the surrounding tissue is relatively unaffected. Very little bleeding occurs as the laser beam seals any small blood vessels in the area. Furthermore, bacteria and viruses are destroyed by the radiation so there is a reduced risk of postoperative infection. In general use, the CO_2 laser is attached to a microscope, allowing the operating area to be viewed and the laser beam to be appropriately directed [3]. A visible helium–neon laser beam is used to align the invisible CO_2 laser beam.

The treatment of cervical intraepithelial neoplasia (CIN) is one of the most mature clinical applications of laser technology. CIN is a generic term referring to a continuum of lesions, and is widely considered to be a precursor of invasive carcinomas. Both surgical and conservative techniques are used in the treatment of CIN.

Surgical techniques include hysterectomy, 'cold knife' conization (removal of part of the cervix) and CO_2 laser conization. Laser conization can be carried out on an outpatient basis. Trials have compared cold-knife and CO_2 laser conization [16]. The success rates were found to be equivalent, but laser conization was found to result in less postoperative haemorrhage and less total blood loss.

A number of conservative treatments are used for CIN, including CO_2 laser ablation and cryosurgery. Laser ablation is the most popular modality in the UK for removal of the lesion. A number of studies have compared laser ablation and cryosurgery but none have found statistically significant differences between the two methods. Typical figures showed success rates of 89% for laser ablation and 93% for cryosurgery [17]. Tests have been carried out in this field using a Nd:YAG laser but the results have not matched those obtained with the CO_2 laser [18].

Vaginal and vulval intraepithelial neoplasia (VAIN and VIN) have much lower rates of occurrence than CIN. However, there has been an increased incidence of VIN in younger women in recent years, so research is under way to develop a form of treatment that preserves anatomical structure and function. The emphasis has been on replacing total or partial vulvectomy by CO_2 vaporization or cryotherapy. No details have been found in the literature of tests carried out to compare the success rates of these two methods, but the success rate is good in the case of laser treatment [8].

Nd:YAG lasers have been investigated in gynaecology for treatment of menorrhagia [19]. Drug therapy includes the use of progestogens and the combined contraceptive pill for young patients, but these treatments do not generally cure the problem permanently. Alternatively, a hysterectomy may be performed for older women. Laser ablation of the bleeding part of the endometrium involves directing Nd:YAG laser energy into the fluid-filled uterine cavity down a quartz fibre through an operative hytoscope. The radiation penetrates relatively deeply into tissues. The procedure takes about 20 min to perform and offers a permanent solution without major surgery.

The CO_2 laser may be useful in the treatment of endometriosis. This is a condition in which there is endometrial tissue outside the uterus. Hormone treatment commonly causes unpleasant side-effects. The laser, coupled with a laparoscope, by vaporizing the endometrial tissue, may offer greater precision in future treatment.

It is expected that use of the CO_2 laser in gynaecology will increase rapidly. The use of the Nd:YAG laser is much less widespread, but research is likely to continue and its use in gynaecology centres should increase as more knowledge is gained about its potential usefulness.

Dermatology

The skin is second only to the eye as the subject of greatest research interest in medical lasers, and dermatologists employ a range of laser equipment, most often using argon and Nd:YAG types.

Laser treatment is well established for removal of port-wine stains, a persistent pink, red or purple mark on the skin often occurring on the face due to abnormal vascular vessels. The marks show little or no tendency to fade with time. While these are clearly not life-threatening, they may be a source of stress to the patient, depending on their location. Initial tests, using a ruby laser to remove these marks, failed due to the absorption spectra of haemoglobin (red light is not well absorbed). The argon laser gives better results. The blue-green light passes through the clear epidermis overlying the vascular network with minimal absorption, and is then selectively absorbed by the haemoglobin in the red blood cells. Heat is generated and the cells are occluded. Tests have shown that patients over the age of 37 respond better to this treatment than younger patients [20].

The Nd:YAG laser has also been tested for this purpose. One study found that there was no statistical difference in the degree of blanching between the argon and Nd:YAG lasers but the Nd:YAG induced more scarring than the argon [21]. The pulsed tunable dye laser can be used more successfully on young patients as it causes less scarring than the argon laser. This is because the pulse duration is close to, or less than, the thermal relaxation time related to the penetration of the particular wavelength in tissue, which means there is less thermal diffusion [22]. A large area may be treated at a time, and a wide variety of stains can be blanched with little pain. Prior to laser treatment there was no satisfactory treatment available. The benefit is an improved quality of life following removal of the stain.

Other vascular lesions can be treated using the argon laser. The effectiveness of this treatment has not been extensively evaluated and research is ongoing in this field.

The main use of the CO_2 laser in dermatology is in the removal of various skin lesions, including cancers. It has also been used for excision of burns prior to skin graft.

The laser has provided treatment in dermatology for conditions for which there was no previous treatment. The emphasis of further work should be the improvement in the quality of life for patients.

Otolaryngology

Lasers have been used in ear, nose and throat surgery for a number of years. The most widely used laser in this field is the CO_2 laser. Again an important feature of treatment is the minimal damage to tissue adjacent to the treatment site. Oral carcinoma represents about

2% of all cancers [8] and the CO_2 laser is now used in many centres for the removal of malignant tumours. Other removal techniques include conventional therapy, radiation, chemotherapy and cryosurgery. For advanced tumours it is often necessary to combine laser and conventional treatment [23]. The CO_2 laser is also used to remove benign or precancerous lesions in the oral cavity.

Another form of cancer which may be treated using the CO_2 laser is cancer of the larynx. Premalignant and malignant tumors have been treated with success [24]. The conventional treatment of laryngeal tumours is radiotherapy, but there are several disadvantages. For example, the treatment takes 5–6 weeks, affects the whole larynx rather than just the affected area and there can be long-term radiation reactions. Laser treatment may be carried out in an outpatient clinic. A study has shown that there is no difference in vocal quality between radiotherapy and laser treatment [25]. Other laryngeal uses of the CO_2 laser include the treatment of recurrent papillomatosis (benign tumours).

The laser has been used to maintain an open passage in the case of oesophageal cancer. Intubation has previously been used to keep the passage open. In general, intubation has a higher success rate than laser treatment, but the quality of swallowing has been shown to be superior if a laser is used. One suggested treatment approach is to use a laser first and, if that fails, use intubation [26]. Other methods of treatment include forceps removal and cryotherapy, but the laser has been found to have the lowest rates of complication [27].

The CO_2 laser is also used in tonsillectomy and adenoidectomy. This was compared to electrocautery and it was found that the laser resulted in less postoperative pain, quicker healing, less blood loss and shorter operative time [28]. The relatively new holmium:YAG laser (2·1 μm) has been found to give an even lower risk of postoperative haemorrhage than the CO_2 laser. However, the cost of the new laser system means that it is unlikely to replace conventional tonsillectomy for some time.

Gastroenterology

Bleeding peptic ulcers are sometimes treated using the Nd:YAG laser for photocoagulation. Conventional therapy is anti-ulcer drugs and emergency surgery. Trials have been carried out to compare the performance of Nd:YAG laser and conventional treatment [29]. It was found that Nd:YAG treatment produces a significant reduction in recurrent haemorrhage and the need for emergency surgery. Another study compared treatment using adrenaline alone, adrenaline plus polidocanol, and adrenaline plus laser therapy for patients with an actively bleeding visible vessel [30]. It was found that adrenaline plus polidocanol, and adrenaline plus laser were equally effective methods for the treatment. Given the cost of the laser system it was recommended that the injection therapy be used.

Another use of the Nd:YAG laser in this field is in the treatment of colorectal carcinoma, a common cause of death in the UK. The conventional treatment is surgical removal of sections of the large bowel. Recently Nd:YAG laser therapy has been used with good results. A general anaesthetic is not needed, and the treatment may be carried out on an outpatient basis. Trials have found that the operation has been successful in 80–90% of patients and there have been low complication rates [31]. Further studies are ongoing to determine suitable laser techniques in the treatment of this disease.

In the USA over half a million cholecystectomies (gall-bladder removal) are performed each year. Recently research has been carried out to identify minimally invasive techniques, such as laparoscopic laser cholecystectomy. This has the advantages of cosmetic preservation, reduction of post-operative pain and shorter hospital stay. Nd:YAG, argon and KTP lasers have been used for haemostasis and dissection of the gall-bladder from the liver bed. It has been found that postoperative hospital stay and the time before returning to work are both reduced by using laser techniques [32].

It is possible that the Ho:YAG laser could be used as a source of a shock wave for lithotripsy. Gall stones and renal calculi could be fragmented using the technique. More research is needed to determine the power needed before this could be used clinically [33].

Physiotherapy

Low-energy laser therapy has been investigated and used clinically by physiotherapists for about 20 years. The past few years have seen a substantial increase in the use of low-level laser therapy (LLLT). The laser treatment of conditions such as rheumatoid arthritis, osteoarthritis and ulcers has been investigated. The use of a laser for tissue healing has also been tested. The wavelengths most commonly used are between 630 and 1300 nm [34]. The average power density used is in the region of 50 mW/cm^2.

It is difficult to interpret information on the physiological effects of LLLT. There has been a wide range of subjects and physical conditions used in tests. Tissues from different regions of different animals have been investigated using different laser types and different dosages. Several theories have been suggested to explain tissue healing, one of which is that growth factors are released when laser radiation penetrates cells. The studies reported in the literature involve different dosage parameters, and descriptions are very limited, so the theories have not been substantiated. It is clear that much work is needed to determine physiological mechanisms and optimum wavelengths for treatment of different conditions.

Treatment of rheumatoid arthritis using LLLT has been investigated by several groups with varying results. Some studies have reported a good response with improvement in hand grip and joint flexibility [34]. However, other studies found no improvement in joint performance [35]. Again different physical conditions have been used so it is difficult to compare the results.

A team from the University of Ulster conducted a survey of physiotherapists in Northern Ireland to establish current clinical practice [36]. Almost all respondents complained about the lack of information available about low-power lasers and suggested dosages. The study also found that there may be a strong placebo effect as patients tend to expect better results from such a 'hi-tech' modality. The conditions which were found to benefit from LLLT included wound healing, soft tissue injuries and pain, but no theories of physiological reactions were discussed.

Laser radiation as a form of therapy is being used increasingly in the clinical field. While the placebo response may be considerable, it should be noted that LLLT is used successfully in agriculture, particularly on horses. It is essential that more work is done to determine the physiological effects and optimum physical conditions for use of a laser.

Other uses of lasers in medicine

Many other specialties in medicine are beginning to make use of lasers as alternative treatments. The Nd:YAG laser is used in urology for the treatment of bladder cancer. The ablation of the tumour is contactless and bloodless, and tumours up to 2 cm in diameter may be totally eliminated by the laser [4]. No general anaesthetic is needed so the treatment may be carried out on an outpatient basis.

In the field of neurosurgery, the CO_2 laser provides surgical precision which was previously unattainable. Surgeons may remove tumours from difficult areas with a 'no-touch' technique. This means that there is little manipulation of brain tissue so the patient's recovery is better. Many laser patients are alert and out of bed the day after the operation [4]. Spinal tumours may also be treated using the no-touch technique of the CO_2 laser, as manipulation of the spinal cord is kept to a minimum resulting in less damage to the cord and to nerve roots.

There is, at present, limited use in orthopaedics for lasers, but research is currently being done to determine the usefulness of lasers for removal of bone cement during revision arthroplasty. The current method used for removing bone cement is mechanical and uses high-speed burrs, reamers and other instruments that often cause fractures or bone penetration, thus complicating patient recovery. The CO_2 laser has been investigated for this purpose with good results to date, but more work is needed before the laser will be used clinically on a regular basis [37]. It is also hoped that lasers will prove to be useful in arthroscopy. They are already widely used in endoscopic surgery so arthroscopy would seem to be an obvious extension. However, few papers have been published on the subject.

New lasers

Lasers have greatly improved treatment in many branches of medicine, though those currently used often require cumbersome delivery systems or fail to precisely ablate joint tissue. Diffusion of heat produced by continuous-wave irradiation produces unwanted zones of damage. The CO_2 laser is capable of precise tissue ablation because the wavelength is strongly absorbed by water. The major limitation of this laser is the lack of an optical fibre capable of transmitting 10·6 μm waves efficiently, as the radiation is absorbed by all currently available fibres: the beam is directed to tissue by a series of mirrors in an articulated arm. In the saline environment of joint surgery the CO_2 laser would cause harmful effects since the radiation is so highly absorbed by water. The ablation depth of the Nd:YAG laser cannot be controlled precisely, while visible wavelength lasers such as the argon require pigmented chromophores for absorption.

New lasers may be capable of solving many of these problems. The Ho:YAG, Er:YAG and the THC:YAG all emit radiation in the mid-infrared region, and optical fibres are available that could carry this radiation to the operative site. Pulsed operation of these lasers enables radiation to be delivered without undue damage to proximal tissues. The Ho:YAG has a wavelength of 2·1 μm and has been investigated for many applications including haemorrhoidectomy, stapedotomy and orthopaedic surgery. It can function well in a saline environment, making it appealing to orthopaedic surgeons.

Table 2 shows advantages and disadvantages of some lasers. More research is needed before new lasers can be developed fully for use in medicine.

Conclusions

This paper has described only a few of the current uses of lasers in medicine. Many more applications are being researched, particularly in the fields of urology, neurology, cardiovascular surgery and orthopaedic surgery. The laser may be used for alignment and measurement as well as a surgical device. The use of lasers in medicine has increased in the past decade, and the next 10 years will see the laser as an everyday tool in many more specialties.

Table 2. Characteristics of medical lasers showing that each laser used has both merits and drawbacks; choice depends on the particular application

Laser	Advantages	Disadvantages
CO_2	Precise ablation	Delivery system (no fibre)
Nd:YAG	Optical fibre available	Dispersive
Argon	Fibre available	Pigmented chromophore needed
Ho:YAG	Fibre available; suitable for saline	Research needed

Until recently, most laser applications were performed using argon, Nd:YAG or CO_2 lasers. There is now a larger range of lasers available so new processes are likely to become amenable to laser therapy.

For future development lasers need to provide more effective treatment with fewer side-effects and complications than conventional treatment. The initial cost of a laser system has in the past prevented installation at smaller hospitals. However, it is now clear that laser systems may be used in many different fields within medicine. Multispecialty use of any laser system would be more cost-effective, allowing many more centres to make use of this useful tool.

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