**Laser Therapy for Cancer Treatment**

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The word laser is an acronym for light amplification of emission radiation, which gives a short explanation on how lasers work. The first laser was created because scientists wanted to make a product, which could emit controlled electromagnetic wavelengths, which were smaller than radar and radio waves, as products of this nature already existed [1]. Charles Townes, a faculty member of Columbia University with help from other members of Columbia University already created a working MASER, or microwave amplification by stimulated emission, and then soon after started looking at the possibility of creating a controlled emission of infrared wavelengths, which were smaller than microwaves [1]. Townes made the discovery that it would be easier to create a device which emits wavelengths smaller than infrared and in the visible light region of about 380 nm-470 nm [1]. He gave this information to Arthur Schawlow and a graduate student of Columbia, Gordon Gould [1]. Schawlow and Gould both figured out how to make lasers of visible light a reality, but it wasn’t until years later in 1960 and many tries that the first laser was made in Hughes Laboratories in New York [1]. Creating products which produce different wavelengths of electromagnetic waves is beneficial because they are composed of photons carrying different energies, which will interact with matter in different ways [2].

Lasers are composed of a power source, an active medium, and a cavity for resonance [2]. The active medium portion of a laser can be a solid, liquid or a gas, but it must be a material where many of the atoms or molecules in the material can brought to a higher energy state at the same time [2]. Although many energy sources exist that excite the molecules in the active medium, a common source for medical lasers is an electric current [2]. An electric discharge into the active medium can cause a population inversion, which excites the atoms or molecules of the material in the medium [2]. When electrons are spontaneously relaxed from a higher energy state, they emit photons [2]. These photons will travel and can cause neighboring atoms to go from an excited state to a relaxed state, resulting in more emitted photons [2]. This phenomenon is called stimulated emission, and it is important in lasers because the photons that are emitted as a result of the original photon will travel in the same direction, have the same phase and will carry the same energy as the original photon [2].

There is one mirror on each side of the cavity, which holds the active medium in a laser [2]. Although both mirrors reflect photons that come in contact with them, one of the mirrors is semi-transparent and allows some photons to pass through it [2]. The mirrors allow photons to reflect back and forth to create a long path of travel, which is necessary for the amplification of light [2]. The structure of the mirrors and the material between them make up the resonance cavity and allow the stimulated emission of the laser to continue as some of the photons are lost through the semi-transparent mirror [2].

All of the photons which are lost through the semi-transparent mirror create the laser beam [2]. The unique aspect of beams from lasers versus other light sources is that lasers are monochromatic and have a very small divergence, which is beneficial for medical purposes because of the precision they provide [2]. The start of using lasers for medical purposes was when a man named Dr. Leon Goldman became interested in figuring out how lasers interact with biological systems [5]. He performed the first laser removal of a skin cancer tumor in 1961, and the application of lasers in the medical world has only grown since then [5].

Traditional cancer treatments such as chemotherapy and surgery can be extremely painful or cause scars, so laser therapy may be a more tolerable method of treatment [3]. Laser treatment of cancer is usually done on superficial tumors such as skin cancer, or the early stages of some other cancers [4]. Lasers can be used to get rid of tumors or decrease the size of tumors and can also be used to decrease the painful effects of surgery by sealing nerve endings and lymph vessels [4]. The most common lasers used for cancer treatment, which have shown to be effective are solid-state lasers, gas lasers and sometimes diode lasers [3]. There are two different methods, which doctors use lasers to treat cancer, one is excision and vaporization of tumors by heat transfer, and the other is through photodynamic therapy.

When a laser beam comes in contact with a human tissue, components of the tissue, such as water, melanin, or blood will absorb the energy held in the photons, which will cause the temperature of the tissue to increase [7]. The transfer of heat to the tissue is dependent on the absorption coefficient, which is a property of the tissue, and the intensity of the laser [8]. These parameters along with others must be calculated to ensure effective treatment and limited damage to tissues surrounding the cancer cells [8]. Another important aspect of the energy transfer to a tissue is the thermal penetration depth which is given by the equation Z(t)=√4kt, where Z is the thermal penetration depth, k is the temperature conductivity of the tissue and t is time [8]. This value represents the depth, which the laser is at 63% of its peak intensity, which can give important information about how a laser will interact with a tissue, and how deep it will go into the tissue [8]. The heat conductivity in the tissue is given by Fourier’s Law, or the equation q=-k∇T where q is the heat flux, k is the thermal conductivity constant and T is the temperature at a point on the tissue [9]. The assumption that this law holds, while thermal current conservation also holds gives the rise to the parabolic heat transfer equation:

-∆T(x,t)+1/α dT/dt(x,t)=1/k S(x,t)

Where α is the diffusivity given by k/pc, where pc is the volumetric heat capacity [8].The term S represents the sum of the heat sources' part of the system, which could be the laser, blood perfusion, or any other metabolic activity, however for laser treatments usually only the laser heat source needs to be accounted for [8]. The heat source function, with the heat source being the laser can be found using the Beer Lambert equation [8]. The above equation, however, is the simplest case, because there is retardation of time, which delays temperature change [8]. Taking the retardation of time for small diffusion time intervals gives the more complicated heat transfer equation with heat sources:

-∆T(x,t)+1/α(dT/dt (x,t)+τ (d^2 T)/(dt^2 ) (x,t))=1/k(S(x,t)+τ dS/dt (x,t))

Where τ is a relaxation or diffusion interval of time [8]. This form gives the equation wave properties due to the second time derivative [8]. To use these equations for medical applications, first the penetration depth, the heat source function and boundary conditions must be determined [8]. After these values have been calculated, the conduction of heat in a tissue can be predicted, which leads to the amount of time a laser should be placed on the tissue and the place the laser should be directed [8].

Another way that lasers can be used to treat cancer is through photodynamic therapy where the lasers act as activators to drugs that cause the death of cancer cells [6]. This kind of therapy works by a person first ingesting a photosensitive drug, or having a photosensitive drug placed topically on cancer cells on or in their body [9]. The photosensitizers are able to stay in cancer cells longer than healthy cells which allows the method to work without harming many healthy cells [9]. A laser of a specific wavelength, which corresponds to what the photosensitizer drug will absorb, and thus what will excite the atoms in the drug is then directed towards the cancer cells [9]. When the photosensitizer atoms are excited, it causes the oxygen in the tumor cells to become reactive [9]. The reactive oxygen species is toxic to the cancer cells because it causes depletion of oxygen and makes the cell unable to use nutrients that it needs to survive, which leads to cell death [9].

One specific type of gas laser, which is used to treat cancer is a CO2 laser, where the substance in the active medium is carbon dioxide [6]. This type of laser can be used to vaporize tissue while causing minimal damage to other tissues around it because it does not travel deep into the tissue [6]. This event is possible because of the energy that the photons of light carry [7]. The photons released from excited atoms in carbon dioxide have larger wavelengths than many other types of lasers, which allows for a faster increase in temperature of human tissue, which has shown to be beneficial in tissue vaporization or tissue cutting [6]. Another type of gas laser commonly used for the treatment of cancer is an argon laser, which means the substance in the active medium is argon [7]. Argon lasers also do not travel deep into tissues, and are many times used to remove pre-cancerous tumors [6]. They are also used in photodynamic therapy as they usually emit a blue-green light between 488-514nm [10]. This wavelength is used with a photosensitizer that absorbs blue-green light because if a higher wavelength laser such as a red laser was used, it would penetrate deeper into the tissue, which could cause damage to neighboring healthy cells [10].

A type of non-gas laser used for cancer therapy is the solid-state laser Nd:YAG or a Neodymium: Yttrium-Aluminum-Garnet laser, which has an active medium consisting of a neodymium doped crystal [6]. This type of laser can travel deeper into tissues and can treat cancers inside of the body using endoscopes and optical fibers [6].

One more type of laser, which has shown to be effective in cancer treatment, although the gas and sold state lasers are probably more effective, is a diode laser [6]. In a diode laser, a semiconducting material is used in the active medium, and the electrons in the material are excited by an electric current [6]. On superficial melanoma cancer cells, in one study this type of laser showed to be 72% effective with no recurrence of the tumors [6].

Laser cancer therapy has relatively few drawbacks regarding pain, discomfort, or scarring after treatments, while other treatments such as chemotherapy or general surgery can cause hair loss and bad scarring. Laser tumor removal is also more precise than the surgical removal of tumors, and usually causes less bleeding, and can result in less harm to healthy human tissues [7]. However, there are many limitations to laser treatments [7]. Lasers for cancer treatment are much more expensive than regular surgical equipment, and doctors must be specifically trained in order to use one [7]. Also, laser treatment has a higher rate of recurrence than other treatments and may need several applications to fully remove cancer cells [7].

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