Basic Principles of Low-Level Laser Therapy and Clinical Applications for Pain Relief

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The purpose of this article is to briefly review some of the basic concepts of low-level laser therapy, clinical indications for its use, and treatment options when applying therapeutic lasers to patients in pain.

The first working laser was presented to the public at a press conference in Southern California in the late 1960s by Theodore Maiman. He demonstrated a ruby laser. The potential for using lasers for surgery was soon explored and rapidly introduced into surgical suites in many countries throughout the world.

A Hungarian physician named Endre Mester performed cancerous tumor treatment experiments on rats, utilizing laser. He found the laser he was using didn’t kill tumor cells because it was underpowered for that purpose, but accelerated wound healing in the surgical sites of the experimental rats. He is the grandfather of photobiomodulation, being the first to observe the healing effects of therapeutic lasers.

There have been more than 2,500 published studies worldwide involving low-level laser therapy, with approximately 120 double-blind studies published. There are several extraordinary effects that have been observed with therapeutic lasers, and phototherapy in general, that make laser therapy unique among the various healing modalities available today. Photobiomodulation produces changes in oxidation/reduction status of the mitochondria which lead to dramatic increases in ATP synthesis. Activation of the sodium/potassium pump alters the cell membrane permeability to calcium.

Phototherapy has been shown to affect cellular activity in the following ways: stimulate cell growth; increase cell metabolism; improve cell regeneration; produce an anti-inflammatory response; produce an edema reduction; reduce fibrous tissue formation; stimulate nerve function; reduce the production of substance P; stimulate long-term production of nitric oxide; decrease the formation of bradikynin, histamine and acetylcholine; and stimulate the production of endorphins. These photobiological responses largely are responsible for the pain-relieving effects often observed in patients treated with phototherapy.

There are three effects that commonly occur as a result of tissue exposure to light photons:
Primary effects due to photoreception and the direct interaction of photons with cytochromes are very predictable and unique to phototherapy. Photoreception generally is followed by transduction, amplification and photo-response, the last of which can be classified as either secondary or tertiary.

Secondary effects occur in the same cell in which photons produced the primary effects; they are induced by these primary effects. Secondary effects include cell proliferation, protein synthesis, degranulation, growth factor secretion, myofibroblast contraction and neurotransmitter modification, depending on the cell type and its sensitivity. Secondary effects can be initiated by other stimuli as well as light.

Tertiary effects are the indirect responses of distant cells to changes in other cells that have interacted directly with photons. They are the least predictable because they are dependent on both variable environmental factors and intercellular interactions. They are, however, the most clinically significant. Tertiary effects include all the systemic effects of phototherapy.  

Primary, secondary and tertiary events summate to produce phototherapeutic activity. The vast majority of therapeutic lasers today are semiconductor lasers.

There are three diode types. The first is an Indium, Gallium-Aluminum-Phosphide (InGaAlP) laser. This is a visible red-light laser diode that operates in the 630-700 nm range. These lasers output light continuously. These lasers also might be pulsed by an electro-mechanical method (duty cycle). A duty cycle output means the power is switched off for part of a second and then switched back on. If it was off for a ½ second and on for a ½ second, that would be referred to as a 50 percent duty cycle. This reduces the average power output by 50 percent. Red-light lasers have the least amount of penetration of the three lasers with a range of 6-10 mm. They affect the skin and superficial tissue.

The second semiconductor laser is a Gallium-Aluminum Arsenide (GaAlAs) laser. This is a near-infrared laser, which means that the light emission is invisible to the naked eye. This laser operates in the 780-890 nm range. This type of laser also has a continuous output of power and is often pulsed on a duty cycle as described above. This laser penetrates 2-3 cm in depth. These lasers often are utilized for medium to deep tissue structures such as muscles, tendons and joints.

The third semiconductor laser is a Gallium-Arsenide (GaAs) laser. This laser is unique in that it always is operated in superpulsed mode. Superpulsing means the laser produces very short pulses of high peak power.
These peak power spikes usually are in the 10-100 watt range, but last for only 100-200 nanoseconds while maintaining a mean power output that is relatively low. This phenomenon is similar to what happens in a camera flash. Superpulsing allows for deep penetration into body tissues without causing the unwelcome tissue effects of continuous high-power output, such as heat production. Superpulsing allows for deeper penetration than a laser of the same wavelength that is not superpulsed, but has the same average output power. Penetration is 3-5 cm or more. Superpulsing also allows for treatment times to be the shortest possible. These lasers are extremely well-suited for medium and deep tissues, such as tendons, ligaments and joints.9

Most phototherapy research has been historically laser-centered. Several studies are now appearing in the literature utilizing light-emitting diodes (LEDs) and infrared-emitting diodes (IREDs). LED/IRED diodes have approximately 80 percent of the effect on tissues as lasers.5 The most commonly used light diodes for phototherapy are: visible red (630 nm, 640 nm, 650 nm and 660 nm) and IRED (830 nm, 880 nm and 950 nm).

These are driven by power outputs up to 100 megawatts or more, and are most often used in clusters of several diodes. Some devices use clusters of a single frequency, while others use a mix of LEDs and IREDs of various wavelengths. There are a few exotic devices that use unusual wavelengths. One interesting device utilizes a cluster of various wavelengths 700 nm and 2,000 nm IR.

Most LED and IRED diodes are made from the following compounds: GaAsP - red light - 640 nm, 655 nm; AlInGaP - blue and red light; InGaN - blue and red light; AlGaIn - blue and red light; and AlGaAs - IR - 880 nm, 950 nm.

Red light at 640 nm has been shown to affect skin, so it might be effective in treating cuts, scars, trigger points and acupoints. Usual depth of penetration is less than 10 mm. The 880 nm IR phototherapy has been shown to affect deeper structures such as bone, tendons, deep muscles or other tissues up to 30-40 mm. These figures are achieved by LED/IRED therapy because of large arrays of 40-60 diodes with a high power output.

Advantages: no tissue damage, broad coverage because of non-coherent light. Disadvantage: possible thermal effects in the devices that cover large areas and have several watts of power output. Several companies are using blue and red LEDs together with IREDS in one pad. They have observed sedation effects in the blue and stimulation effects in the red. Essentially all LED/IRED devices are pulsed on a 50
percent duty cycle.

Historically, most laser manufacturers produced therapy devices that were of only one wavelength. This necessitated the clinician to have several probes or emitters, each of a different wavelength, in order to ensure adequate coverage of various tissues. Today, phototherapy devices that have combinations of laser diodes, LEDs and IREDs, are increasingly available. This allows for deep penetration by the laser and more superficial and broader irradiation by the LEDs and IREDs. There also are companies that manufacture devices that have cluster or arrays of several laser diodes.\textsuperscript{10}

Adequate clinical assessment is important in determining whether or not a patient is a good candidate for laser therapy. It can be used alone or in combination with other modalities. Eastern European studies have shown phototherapy to be an effective adjunct in more than 200 conditions.\textsuperscript{11}

FDA clearances have been granted to several phototherapy manufacturers that distribute their products in the U.S. The on-label uses for the devices primarily are for pain management. There have been a considerable number of clinical studies of the responses to laser therapy in a broad number of conditions. The following painful conditions have been shown to be quite responsive to phototherapy: carpal tunnel syndrome, muscle strains, tendonitis, neck and low back pain, fibromyalgia, joint sprains, tennis/golfer’s elbow and soft-tissue injuries.\textsuperscript{12} Phototherapy applications are safe and usually require only a few minutes to perform. Established protocols and tissue dosages have been developed that make clinical application relatively simple. Many phototherapy instruments have preset programs that take all of the guesswork out of the process.

There are several application techniques for utilizing low-level laser therapy on patients. The first is tissue saturation of the involved area. This may be performed by pressing the emitter or probe on the skin and holding there for a period of time and then moving it to an adjacent area, in a grid pattern until the entire area is covered. Scanning or back-and-forth movement for the duration of the treatment time also might be employed for saturating the tissues.

Laser tissue penetration is enhanced by maintaining firm pressure on the skin surface with the emitter or probe. This helps displace capillary blood flow in the superficial tissues, which decreases blood flow to the treatment area. This is desirable because photon penetration into the tissue is inversely proportionate to the amount of water content in the tissues. Blood has high water content, so it will tend to absorb more of the photon energy. This will result in less penetration into the deeper tissues.\textsuperscript{13} Phototherapy devices that
utilize a combination of laser and LED/IRED combinations should be used in direct contact with the skin for the additional reason that these nonlaser light sources are noncoherent and lose their focus as they are distanced from direct contact with the skin.

The second treatment approach is to treat trigger points. This is accomplished by using a stationary contact on the trigger point as described above. The use of an algometer is beneficial to obtain a comparison of pain level prior to treatment and post treatment.

The third treatment approach is acupuncture point stimulation or laserpuncture. There have been considerable numbers of studies performed on laser stimulation of acupoints. The emitter or probe can be placed over the acupoint or a special acupoint probe may be used. Clinical experience has shown that the more these three techniques are combined together during treatment sessions, the faster and more long-lasting are the results.

The North American Association for Laser Therapy (NAALT) has compiled the following list of contraindications: pregnancy (over the pregnant uterus); cancers (over the tumor site); treatment over the thyroid gland; treatment over pediatric joint epiphysis; treatment for transplant patients or other immunosuppressed patients; or photosensitive patients. Caution should be used when considering the use of laser phototherapy on patients that recently have undergone steroid or Botox treatment. Laser therapy, in general, is safe and can often be used where other physical modalities are contraindicated such as with pacemakers or metal implants.

Laser phototherapy can be of value in the mitigation and elimination of many painful conditions. Laser phototherapy is easily applied to patients with relatively short treatment times, depending on the power output of the device, the wavelengths used and the size of the area to be treated. There are no known permanent or serious side effects from appropriately applied laser therapy.

References


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