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Light Therapy: Making the Right Choice in Laser Therapy (Part 1)

Making the right choice of laser for your light therapy can be extremely confusing because the literature available on light therapy is not only confusing but contradictory (Basford, 1993). Laser light has unique physical properties that no other light source or LED has. There is a big difference between a colorful brochure and the clinical efficacy of the unit being sold. To date, laser instruments have been sold which do not even contain a laser. To help you make the right choice, this article defines the common terms used in light therapy and presents the biological basis of the unique clinical efficacy of Low Level **LASER** Therapy.

The word ***LASER*** is an acronym for ***Light Amplification by Stimulated Emission of Radiation***. Scientists recognize lasers by two parameters. Laser light is ***coherent*** (single wavelength) and ***collimated*** (focused). Coherent light means waves of the light quanta or photons are synchronous and move in the phase with each other. By collimating or focusing a specific wavelength of light, energy can broadcast great distances and remain a focused dot of energy. Advertised light therapy units such as the LED, CO2 and infrared or near-infrared lasers, are in general, not collimated. Removing the collimator from a laser will cause the light array to look just like an LED or any other colored light, but the biological and clinical effects are not the same. Laser light is the only source of coherent and collimated light. This underlies the biological basis of light therapy.

While there is no legal definition for “Low-Level Laser Therapy (LLLT), most scientists and clinicians agree that Low-Level means that the power output (2 to 5 mW) is low enough not to raise the temperature of the tissue being irradiated by more than 1 degree Celsius (Turner and Hode 1999). The FDA classifies lasers with this power output as a Class IIIa laser. Any potential danger from a Class IIIa laser results from direct irradiation of the eyes. Thermal damage is not possible. Class IIIa lasers allow LASERS to be used as therapeutic tools to, “… ***relieve pain and suffering and above all else, DO NO HARM***…”

In marked contrast, the highly advertised, High-Power infrared (IR), or near-infrared lasers (NIR), classified by the FDA as Class IIIb-IV, have power outputs much greater than 10 mW. Higher-output power can induce marked elevations in tissue temperature (e.g., 110 mW, 2.45 C: 142 mW, 4.74 C, Gurevich, Filonenko, and Salansky, 1994). While High-Power lasers can produce symptomatic pain relief, the mechanism of action involves thermal ablation of tissue, including neuron receptors, cell membranes, and intracellular proteins. (Karu, 998, 2002). While symptomatically effective for short durations, these lasers are not therapeutic and potentially dangerous for both operator and patient.

Low-level light therapy works by stimulating a cell’s innate metabolism. Again, the effects are ***biochemical, not thermal***, and therefore cannot damage living cells (Karu, 1998, 1999, 2002). The therapeutic effects of LLLT result from biomodulation of a tissue.

Low-Level Laser Therapy is safe for both operator and patient. LLLT lasers are therapeutic because they allow living tissue to maintain or return to homeostasis without damaging tissue (Karu, 1998).

Biomodulation is defined as changing the natural biochemical response of a cell or tissue within the normal range of its function. LLLT acts as a trigger to turn on or off the cell's own metabolic processes in response to a stimulus. Light energy, or quanta, triggers some change in cellular metabolism. Biomodulation resulting from exposure to light energy or photon transfer is termed ***photobiomodulation,*** the effects of which are biochemical, not thermal.

Photobiomodulation results from transfer of energy from a photon to a photon acceptor on the cell, mitochondrial, or nuclear membrane or to some intracellular protein. Photon acceptors found within biological tissue are called ***chromophores.*** Chromophore literally means "lover of color". Biological chromophores are pigmented (colored) substances such as amino acids, nucleic acids, mitochondrial enzymes, hemoglobin, melanin, serotonin, retinal rodopsin, etc., and are found throughout living tissue.

Four distinct biological effects occur when using LLLT, i.e., when photon energy is transferred to a biological chromophore. These include:

1. Growth factor production occurs within cells and tissue in response to increased ATP and protein synthesis. This initiates mitosis, cell proliferation by changing the cell, mitochondrial, or nuclear membranes permeability to monovalent (Na+, K+) and divalent (Ca++, Mg++) ions (Karu 1987, 1998, 2002).

2. Pain relief results from suppression of the nociceptor response mediated by increased serotonin and endorphin release (Sumano et al., 1987a, 1987b).

3. Immune-modulation and mitigation of the inflammatory response occur because the mononuclear phagocytic cells, mast cells, and leukocytes are stabilized preventing the release of harmful inflammatory mediators (Amano 1994). In addition, vasodilatation and increased microcirculation allows a rapid return to homeostasis and promotes first intention healing (Sumano 1987a, 1987b; Fiszerman and Rozenbom 1995).

4. Direct trigger point stimulation allows direct release of endorphins and other endogenous pain mediators such as serotonin, VIP, substance P, prostaglandins, etc. (Kaada, B and Eielson O, 1983, Kaada, Olsen and Eielson,1985).

Propagation of light though tissue is regulated by ***reflection***, ***penetration,*** or ***absorption and transfer of energy*** of light quanta to the cell. This is laser dependent.

Reflected energy becomes scatter radiation and is dangerous to both operator and patient. This is a natural ***in vivo*** protection mechanism. The body could never control its internal environment, temperature, and therefore cellular metabolism if all exposed photon energy was transferred to the tissue. The majority of energy from uncollimated and noncoherent light sources is reflected off the skin surface. Most infrared light sources are uncollimated or noncoherent, or both, and depend on scatter or reflection to reduce the thermal damage due to irradiation. Therefore, very little photon energy is transferred to the tissue. Biomodulation does not occur.

As advertised, photon energy from high-power infrared lasers ***penetrates*** deep into the tissue. Again, this is a physical and thermal phenomenon, not a therapeutic phenomenon. Energy is dissipated as heat. Thermal activation overrides the cells homeostatic metabolic state. The cell may be turned on or off but not in a functional manner. This can cause damage deep in tissues, out of sight of the clinician.

Furthermore, energy transfer to a biological chromophore does not occur.

When light quanta are **absorbed, *energy is transferred*** to water, some organic molecule, or to one or more ***chromophores*** within tissue. ***Biomodulation*** occurs because the absorbed photon ***changes the energy state of an electron (mitochondrial electron transport chain)***, donates ***an electron*** to a re-dox molecule (Cytochrome oxidase, hemoglobin, melanin, serotonin, porphorin ring, amino acid, nucleic acid etc.,), or ionizes ***a chemical bond*** (ion or protein channel on the cell, mitochondrial or nuclear membrane) thereby producing a cellular response which changes the cell's homeostatic set point .

Within the cell, the signal is transduced and amplified by a photon acceptor (chromophore). When a chromophore first absorbs light, ***electronically excited states*** are stimulated, primary molecular processes are initiated which lead to measurable biological effects. These photobiological effects are mediated through a secondary biochemical reaction, photosignal transduction cascade, or intracellular signaling which amplifies the biological response.

The ***ionizing*** effects of LLLT allow photon acceptors to accept an electron. This turns on the oxidation-reduction cycle of the stimulated chromophores such as Cytochrome oxidase, hemoglobin, melanin, and serotonin. Changing the re-dox state of the chromophore changes the biological activity of that chromophore e.g., hemoglobin changes its oxygen carrying capacity. This is in contrast to the destructive ionizing effect of x-rays, which remove or disrupt electrons from an atom or molecule and damages tissue.

When photon energy ***breaks a chemical bond,*** changes occur in the allosteric proteins in cell membranes (cell, mitochondrial, nuclear) and monovalent and divalent fluxes activate cell metabolism and intracellular enzymes directly. Direct activation of cell membranes alters ion fluxes, particularly calcium, across that membrane. Changes in intracellular calcium alter the concentrations of cyclic nucleotides, causing an increase in DNA, RNA, and protein synthesis, which stimulate mitosis and cellular proliferation.

When all of the above occurs correctly, the photon activates a chromophore and that single enzyme molecule rapidly catalyzes thousands of other chemical similar to the well known, calcium regulated, 2nd messenger cAMP cascade. This ***biological amplification*** process explains how low-power laser therapy can produce such profound systemic, cellular, and clinical effects.

One of the most confusing aspects of light therapy is dozens of published reports, which fail to find any effect from LLLT. As with any treatment, clinical efficacy depends on diagnosis, dosage, treatment technique and individual reaction. Similarly, each stage of the biomodulation cascade depends on additional laser specific factors including the ***light source, wavelength, irradiation dose***, ***power density***, and tissue specific factors including target ***chromophores*** and the ***functional metabolic state*** and ***composition*** of the irradiated tissue. Alterations in any of these parameters can minimize or cancel the effects of light therapy. Here are some basic examples:

Light sources: A cell's response to light differs markedly ***in vivo*** and ***in vitro.*** The coherent properties of laser light are not important in cell suspensions or tissue culture monolayers. ***In vitro***, coherent or noncoherent light (both lasers and LED's) with the same wavelength, intensity, and dose, can stimulate the same biological response.

However, ***In vivo,*** in living tissue, only photons of coherent light are able to pass through optical windows in cell membranes to become accepted by photon acceptors (chromophores).

Coherent light is only created by a LASER light source, not from LED or SLD light sources. Even coherent light, if left uncollimated, will for the most part, reflect off the skin as dangerous scatter radiation. Coherent, collimated, laser light has, by far, has the greatest therapeutic potential. Because laser light triggers the cells own homeostatic mechanism, only low intensities and doses are required for dramatic biological responses.

Wavelengths: Every chromophore has an absorption coefficient for peak activation, which is wavelength specific. However, each chromophore has a wide range of wavelengths in which it will accept or donate electrons. Within living tissue, peak activation of a chromophore can occur within a broad range of wavelengths (e.g., oxygenated hemoglobin has absorption peaks at 420 and 577 nm; reduced hemoglobin at 560nm). Wavelengths longer than 1200 nm (infrared) and shorter than 200 nm (ultraviolet) are absorbed by inter- and intracellular water.

Wavelengths of 620-720 nm are typically better able to penetrate optical windows in cellular membranes because their photons are not easily absorbed by living tissue, which on average, are composed of 70-80% water. Chromophores found in eukaryotic (mammalian) tissue have peak activation spectra between 600 nm to 720 nm. Since laser light acts as a trigger for normal cellular metabolism, it is not necessary to utilize a wavelength that strikes the peak activation of each chromophore. It is only necessary for the wavelength to fall within the spectra of the chromophore. The wavelength of 635 nm is contained within the spectra of the chromophores found in mammalian tissue and therefore has the potential to biomodulate all eukaryotic tissue.

Irradiation Dose: The product of power density (mW) and exposure time defines the irradiation dose and is measured in Jules of energy per square centimeter (J/cm^2). This is an extremely important parameter for laser treatment and biomodulation. Scientists have shown the therapeutic efficacy of LLLT is enhanced by repetitive low doses within a specific time in contrast to the same total dose in a single treatment (Abergel, et. al., 1984). In addition, the biomodulation effects of LLLT are cumulative. Repeated doses within relatively short intervals produce greater biological responses than single frequency lasers (Mester, Mester, Mester, 1985). Doses, which are too low, produce no effect. Doses, which are too high, produce no effect or dampen biological activity (Kana et. al., 1981). Each biological tissue has an optimal dose, which is laser dependent [e.g., skin: 1 J/cm^2 – HeNe laser (Mester, 1986); Fibroblast: < 1 J/cm^2 – GaAs laser (Abergel et. al., 1984); Trigger point doses: 0.1 J/AP-point regardless of laser type (Karu, 1988)].

Power density from 2 to 5 mW is adequate to activate mammalian chromophores. Power higher than 5 mW may exceed the activation levels of some chromophores. The greatest biomodulation is created with repeated doses of pulsed collimated laser light at or around 5 mW of power.

Chromophore response is dependent upon the ***functional metabolic state*** and ***composition of the tissue*** at the time of irradiation. LLLT produces separate responses in separate tissue based on the active chromophore within that tissue, e.g. bronchial tissue (mast cells), skin (melanin). Healthy, injured, and malignant tissues absorb light, or

transfer energy differently because they contain different chromophores, and are in different metabolic states. This explains the wide array of therapeutic effects of the LLLT in damaged tissue and the lack of response in healthy tissue.

The most dramatic examples include the different effects of LLLT irradiation on healthy tissue, inflamed tissue, and malignant tissue. Healthy tissue does not contain a high concentration of biologically active chromophores (e.g., biogenic amine, histamine, serotonin, VIP, substance P) while inflamed tissue does. LLLT can mitigate the inflammatory response by stabilizing mononuclear phagocytic cells, stimulating leukocyte chemotaxsis, and preventing mast cell degranulation. This prevents the release of histamine, and other biogenic amines, which cause the cellular infiltration responsible for the four cardinal signs of inflammation: redness, heat, pain, and swelling. LLLT dampens the inflammatory cascade, mitigates inflammation, and allows first intention healing. Similarly, malignant tissue is defined by its high mitotic index, which supports the rapid, uncontrolled growth of cancer. Mitotic cells appear insensitive to LLLT irradiation while injured and dormant cells can be stimulated to divide.

While LLLT may have no effect on a healthy, normal cell, it has profound biological and therapeutic effects on inactive, sick or injured cells. The power of LLLT lies in the fact that injured cells respond to irradiation, turning on or off, allowing the cell to return to, or maintain, cellular homeostasis. In short, LLLT allows the cell to heal itself.

In conclusion, for safe and effective light therapy, the ideal therapy device should be a ***low powered*** (between 2 and 5 mW), ***laser*** (capable of producing collimated and coherent light), which produces ***wavelength*** between 600 than 720 nm, and is capable of rapidly delivering ***pulsed frequencies*** to tissue.

Our next article will cover ***frequency biomodulation***, the key to changing today's standard laser into tomorrow's advanced therapeutic laser instrument.

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