LOW-LEVEL LASER or LED THERAPY IS PHOTOTHERAPY

Kendric C. Smith

Emeritus Professor, Radiation Oncology (Radiation Biology)
Stanford University School of Medicine
800 Blossom Hill Road, Unit R169, Los Gatos, CA 95032
kendric@stanford.edu
www.stanford.edu/~kendric/

All too frequently, people in the low-level laser and light emitting diode (LED) phototherapy field are untrained in the basics of photobiology. This can lead to bad science and bad clinical trials, and can contribute to conflicting results concerning a given endpoint. Low-level laser and LED phototherapy will continue to exist outside of the mainstream of science and medicine until the authors, reviewers, and editors learn the fundamentals of photobiology. The purpose of this article is to explain some of these fundamentals (1).

The Basics of Photobiology

The *First Law of Photochemistry* (and photophysics) states that: light must be absorbed for photochemistry (or photophysics) to occur. This is a simple concept, but it is the basis for performing photobiological experiments correctly. Since photobiological and phototherapeutic effects are initiated by photochemistry (or photophysics), if light of a particular wavelength is not absorbed by a system, no photochemistry (or photophysics) will occur, and no photobiological effects will be observed, no matter how long one irradiates with that wavelength of light. Many papers in the low-level laser and LED phototherapy literature would not have been published (and should not have been published), if the authors and the reviewers had known the First Law of Photochemistry.

An *Absorption Spectrum* is a plot of the probability that light of a given wavelength will be absorbed by the system under investigation. Each chemical compound has a different absorption spectrum, because of its unique electronic structure. Each of the wavelengths absorbed by a chemical compound will be absorbed to different degrees, again because of the unique electronic structure of the compound. Therefore, an absorption spectrum of the biological system that one is interested in will immediately tell the probability that light of a given wavelength will be absorbed, and therefore the possibility of producing a photobiological effect.

Once a photobiological response is observed, the next step should be to determine the optimum wavelength and dose of radiation to produce the effect, i.e., an *Action Spectrum*. An action spectrum is a plot of the relative effectiveness of different wavelengths of light in causing a particular biological response, and under ideal conditions it should mimic the absorption spectrum of the molecule that is absorbing the light, and whose photochemical alteration causes the biological effect. Thus, an action spectrum not only identifies the wavelength(s) that will have the maximum effect with the least dose of radiation, but it also helps to identify the target of the radiation. For example, the action spectrum for killing bacteria mimics the absorption spectrum of deoxyribonucleic acid (DNA). This result is understandable in view of the unique importance of DNA to a cell.

A requirement for a good paper on photobiology is to specify everything about the light source, i.e., wavelength(s), power, dose, area of exposure, time, etc., etc. There are published experimental and clinical studies that were conducted with good scientific methodology, but they did not describe the light source, therefore these studies cannot be repeated or extended by another author. Such papers are useless.

Low-Level Laser Phototherapy

So many acronyms are used in this field that it is confusing to readers, e.g., low level laser therapy (LLLT), low power laser irradiation (LPLI), low power laser therapy (LPLT), low energy laser irradiation (LELI), etc., etc. It would be a great boon to the field if there could be some standardization of nomenclature. Since lasers just produce light, I would urge the use of the simple and correct term, phototherapy.

The wavelength of light produced by the laser must be specified instead of these acronyms, and be repeated throughout the text. Also, a laser should be chosen for the wavelength of light that it produces, not because "The selection of such a laser for therapeutic use was based on its safety and commercial availability."

Low-level laser phototherapy uses radiation both in the visible (400 - 700 nm) and in the near-infrared (700 - 1000 nm) regions of the spectrum.

[Note: Some authorities list the range of visible light from 380 - 780 nm, because some people can see a broader range of wavelengths.] When a photon is absorbed by a molecule, the electrons of that molecule are raised to a higher energy state. This excited molecule must lose its extra energy, and it can do this either by re-emitting a photon of longer wavelength (i.e., lower energy than the absorbed photon) as fluorescence or phosphorescence, or it can lose energy by giving off heat, or it can lose energy by undergoing photochemistry. Photobiological responses are the result of photochemical and/or photophysical changes produced by the absorption of nonionizing radiation.

Karu (2) has shown that visible and near-infrared radiation is absorbed in the respiratory chain molecules in the mitochondria (e.g., cytochrome c oxidase), which results in increased metabolism, which leads to signal transduction to other parts of the cell, including cell membranes, and ultimately to the photoresponse (e.g., stimulation of growth).

For phototherapy, one not only needs to use the proper wavelength of light, but also the proper dose of radiation. Running action spectra for some of the more common clinical problems that use phototherapy would greatly enhance the field. Such results would ensure that the proper wavelength and dose of radiation are always used in the future, and it would help to standardize the profession. Think of each wavelength of light as a different drug, and therefore the need to establish which drug is best, and also what is the optimum dose and treatment schedule.

Even with the proper wavelength and dose of radiation, phototherapy will not be effective on every system and/or situation. The magnitude of the phototherapy effect depends on the physiological state of the cell at the moment of irradiation. It has been observed that there is often no phototherapeutic effect observed when irradiating fresh experimental wounds, while an effect is observed for "old" wounds (3). Light will only stimulate cell proliferation if the cells are growing poorly at the time of the irradiation. If a cell is fully functional, there is nothing for radiation to stimulate, and no therapeutic benefit will be observed. An analogy is that patients will not show a beneficial effect of vitamin therapy if they already receive an adequate supply of vitamins in their daily diet.

It should be cautioned that an excessive dose of radiation can be detrimental. Thus, at proper doses of light there can be a stimulation of growth, but at high doses an excessive amount of singlet oxygen can be produced, and its chemical action can be detrimental to cells (3).

Lasers Are Not Magical

All too often the laser phototherapy literature is written as if a laser is magical. Lasers can seem magical if their unique properties of micro-dot focusing, high intensity, possibility of ultrashort pulses, coherent radiation (i.e., the light waves are all in phase), and monochromaticity are all made use of. If the first four properties are not useful in a particular application, then a laser is just an expensive light bulb, whose emitted radiation follows (except for coherence) all of the same laws of physics and chemistry that the same wavelength of radiation from a conventional (non-coherent) light source follows.

One practice that has fostered the misconception that lasers are magical is the use in publications of such vague terms as "He-Ne laser exposure" or "Argon laser therapy", without ever specifying the wavelength of light that the lasers produce.

No significant difference was found for growth stimulation regardless of whether the light used was generated by a laser or from light of the same wavelength from a filtered incandescent lamp (3). These results further support the conclusion that lasers are not magical; it is the light that they produce that yields the biological effect.

More and more papers are appearing in the therapy literature using non-coherent light sources such as LEDs. In general, they are less expensive than lasers, and as discussed above for laser studies, all the characteristics of the light emitted by LEDs must be specified if a paper is to be useful.

Conclusions

Phototherapy, using low intensity radiation in the visible or near-infrared region, whether from a laser, an LED, or a filtered incandescent lamp, can be beneficial in a number of clinical situations, from pain remission to wound healing. Unfortunately, this type of therapy is not yet accepted in the mainstream of science and medicine, because many of the studies have been conducted without a proper understanding of the properties and the biological effects of light. In addition, many studies have been conducted without proper scientific methodology.

This paper is a plea to low-level laser and LED phototherapy groups, societies and journals, to raise the standards for running and publishing experiments and clinical trials by learning the basics of photobiology, and thereby accelerating the acceptance of this important field into the mainstream of science and medicine, and thus make this type of therapy more widely available for patients who could benefit from it.

References:

1. Modified from: Smith, K.C. (2005), Laser (and LED) Therapy Is Phototherapy, Phtotomedicine and Laser Surgery, 23, 78-80.

2. Karu, T. (2003). Low-power laser therapy. In: Biomedical Photonics Handbook (T. VoDinh, ed.) CRC Press, Boca Raton, FL, 48, pp. 1-25.

3. Karu, T. (1989). Photobiology of low-power laser effects. Health Physics 56, 691-704.

Suggested Reading:

Ten Lectures on Basic Science of Laser Phototherapy, Karu, T, Prima Books AB, Sweden (2007).

The Science of Low-Power Laser Therapy, Karu, T, Gordon and Breach Science Publishers, The Netherlands, (1998).

The Science of Photobiology (2nd ed), edited by Smith, KC, Plenum Press, New York, (1989).

04/02/08
06/02/11

[TOP]