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Low Level Light Therapy is the application of very low power red or near infrared light for wound healing or other therapeutic purposes.

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Laser and LED Therapy is Phototherapy

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All too frequently the people in the 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. Furthermore, it diminishes the stature of the field, and delays the admission of laser (and LED) phototherapy into the mainstream of science and medicine.

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

There are some basic aspects of photobiology that must be considered in a study of phototherapy in order for the study to be valid and accepted by the scientific community.

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), unless light of a particular wavelength is 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. A number of papers in the laser (and LED) phototherapy literature would 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 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 a paper is useless.

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, preferably throughout the text in place of any acronyms. 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."

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 light as a drug, and therefore the need to establish which drug is best, and also 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. For example, when irradiating fresh wounds, the effect of the irradiation can be minimal or nonexistent. This happens when cellular proliferation is active and the regeneration of the tissues is occurring at a more or less normal rate. This may explain why 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 would be that patients will show no 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, as is the case for laser phototherapy, 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 even specifying the wavelength of light that the authors are using.

Furthermore, there is no significant difference whether the light used to stimulate growth was generated by a laser or from non-coherent light of the same wavelength from a filtered incandescent lamp.² 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, in phototherapy it is the wavelength of the light that is important, not the coherence or lack of same. As with laser studies, all the characteristics of the light emitted by LEDs must be specified if a paper is to be useful.

Conclusions

Phototherapy, whether using low intensity radiation in the visible or near-infrared region 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, the absence of this type of phototherapy from the mainstream of medicine makes it unavailable to patients who could benefit from it.

This type of therapy has not yet been accepted into the mainstream of science and medicine, because many of the studies have been conducted without a proper understanding of the properties and biological effects of light. In addition, many studies have not been conducted with proper scientific methodology.

In all studies using light, it is absolutely necessary to specify the wavelength(s) of light used, the area of irradiation, the dose of radiation (whether incident or absorbed), time, etc.

This paper is a plea to 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 field into the mainstream of science and medicine.

References

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

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