

Pain Relief by Phototherapy:

What it does & how it does it

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Phototherapy is the application of light and infrared radiation to the skin or mucous membranes, often by means of low intensity lasers, to relieve pain and stimulate tissue repair. It produces its effects by modulating cell activity. Phototherapy has been used throughout Europe, Canada and Japan for over 30 years. During this time medical treatment with phototherapy has passed from infancy to early maturity. Maturity has made its mark; the question is no longer if phototherapy is effective when used correctly, but how to use it optimally. Phototherapy has now reached the USA, with many devices receiving marketing approval from the FDA. Its benefits to patients can be excellent, significantly reducing both acute and chronic pain. Our aim in this article is to introduce more pain practitioners to it so that more patients can experience these benefits.

The primary source of the photons that comprise electromagnetic radiation, including the wavelengths of light and infrared radiation used in phototherapy, is sunlight, exposure to which has been used for many centuries, and for more than its well known feel-good effects. However the ultraviolet end of the electromagnetic spectrum can be damaging, so for pain relief and the stimulation of tissue repair only

the visible and near-infrared parts of the spectrum are now used. What matters is the wavelength. This determines the color of the radiation. The wavelength must be such that the photons are absorbed. The mitochondria and membranes of cells contain cytochromes which selectively absorb photons transmitted at specific wavelengths. For example, cytochrome C oxidase, present in the mitochondria, the power-packs of the cell, absorbs red light. The absorbed photons then act as a stimulus, triggering cell activity that results in pain relief and the stimulation of healing where this is delayed.

Although most injuries heal rapidly, others, particularly chronic skin wounds, are notoriously difficult to heal and can be painful. Once acute inflammation has been initiated in them, for example by debridement, phototherapy can accelerate the healing of such injuries. According to Tuner and Hode (2002) 'Laser therapy for wounds is ideal, since it promotes healing and reduces pain at the same time'¹. Its routine use could improve the quality of life for the millions of people with chronic wounds with massive financial savings to health care providers.

What is phototherapy?

Phototherapy is the application of low intensity light or infrared radiation to skin or mucous membranes to relieve pain and improve tissue repair. The photons applied to injured tissue during phototherapy are generally of red light and/or near-infrared radiation, although some devices utilize blue and green light. The photons can be produced by low intensity lasers, though monochromatic superluminous light emitting diodes (LEDs) are also used. The term 'laser' is an acronym for **L**ight **A**mplification by the **S**timulated **E**mission of **R**adiation. Phototherapy is also known as low intensity laser therapy (LILT), low level laser therapy (LLLT) and photobiomodulation (PBM). The term laser (photo) biostimulation is also sometimes used, particularly in the USA, sometimes being abbreviated to 'biostim'. Phototherapy or LILT, by whichever of the above synonyms it is described, is a generic term for the therapeutic application of 'relatively low output (< 500mW) lasers and monochromatic superluminous diodes for the treatment of disease and injury at dosages (usually < 35J/cm²), generally considered to be too low to effect any detectable heating of the irradiated tissues'². However, during low-energy treatments such as LILT, the absorbed energy can produce microthermal effects eliciting chemical changes of therapeutic value³. The temperature increases involved are usually too low to be detected, although the local stimulation of blood flow in cold regions of the skin may produce a feeling of warmth.

In contrast to phototherapeutic LILT devices, high intensity (1-30W) surgical lasers are used in focussed mode and produce so much heating that they vaporize tissue at their focal spot. Moving outwards from this spot the level of heating decreases, producing coagulation of proteins and therefore arresting bleeding around the vaporized tissue. Further outwards still the power is reduced to a level where heating is undetectable but where phototherapeutic microheating occurs, reducing pain and improving tissue repair. Thus high intensity, surgical, lasers although predominantly tissue destructive, can induce the phototherapeutic effects of pain relief and improved healing adjacent to the tissue they vaporize and coagulate.

How does phototherapy affect cells?

Phototherapy produces its effects on pain relief and repair by modulating cell activity. Whether stimulation or inhibition occurs depends on the metabolic status of each cell³.

When applied correctly, the photons absorbed during the application of phototherapy can stimulate the healing of chronic wounds⁵ and of acute wounds if these are healing slowly⁶. The wavelength of the photons is particularly important. To produce an effect, the photons must be absorbed, and absorption is wavelength-specific. Different substances absorb light of different wavelengths. Mitochondria absorb red light because they contain cytochrome C oxidase, which is a photon acceptor for red light. Since mitochondria are found in all animal cells except mature mammalian red blood cells, virtually all cells absorb the photons of red light and, if sufficiently sensitive, can be affected by them. Some cells absorb some wavelengths of IR radiation, while other cell types absorb other IR wavelengths, for example, macrophages absorb 870 nm IR whereas mast cells⁷ do not; it may therefore be possible for specific cell types, e.g. injured neurons, to be targeted for activation leaving others unaffected. Once cells have absorbed the photons a cascade of biochemical events occurs resulting in their activation.. Phototherapy devices produce powers too low to damage the cells but high enough to act as a trigger that the cells respond to by modifying their activity.

Pain associated with tissue repair

When tissue is injured it generally repairs. This repair consists of three overlapping phases:

- **Acute inflammation**, when dead or damaged tissue and infective organisms are removed from the site of injury and when cytokines, growth factors essential for repair, are secreted. It is characterized by calor (heat), rubor (redness), turgor (swelling due to edema) and dolor (acute pain that normally ends when the inflammation resolves). It is not a disease but the normal response of the body to injury. Chronic inflammation, in contrast, is a disease associated with chronic pain.
- **Proliferation**, when granulation tissue rich in blood vessels, cytokine-producing macrophages, and fibroblasts develops at the wound site. The cytokines stimulate mitogenesis (cell division) and angiogenesis (blood vessel formation). At first this is pain free though there may be some pain during the growth of nerve fibers into the granulation tissue.
- **Remodeling**, the replacement of granulation tissue by scar tissue, may be painful if nerve fibers become trapped in the scar tissue or if a neuroma develops. This pain can become chronic.

How does phototherapy relieve acute pain?

Phototherapy can accelerate the resolution of acute inflammation. The swelling and pain are therefore reduced more quickly than would occur without treatment. The value of acute inflammation is that during it the cytokines necessary for the onset of the proliferative phase are secreted by macrophages and other cells. Phototherapy accelerates this secretion. In contrast, anti-inflammatory drugs, though

they reduce edema and relieve acute pain, can inhibit the secretion of some cytokines and produce other adverse side effects. Phototherapy is therefore preferable to treatment of acute inflammation with anti-inflammatory drugs, unless this treatment is of short duration.

The following are examples of conditions producing acute pain which can be treated successfully with phototherapy¹:

- Acute wounds
- Viral infections (e.g. cold sores and shingles)
- Sports injuries
- Whiplash-associated injuries

How does phototherapy relieve chronic pain?

Chronic pain is dependent upon nerve conduction and is often associated with chronic inflammation. The following are examples of conditions producing chronic pain which can be treated successfully with phototherapy¹:

- Carpal tunnel syndrome
- Chronic wounds
- Epicondylitis
- Fibrositis/Fibromyalgia
- Headache/Migraine
- Plantar fasciitis
- Tendonitis/Bursitis
- Neck/Back pain
- Trigeminal Neuralgia
- Whiplash associated injuries.

There is extensive documentation in support of the use of phototherapy in the treatment of these conditions¹. Studies investigating the use of phototherapy for the treatment of both acute and chronic pain draw upon parameters defined by *in vitro* research which have been extrapolated, with variable results, to clinical settings. A biostimulatory window has been found; the parameters of the window include wavelength (nm), power density (W/cm^2) and energy density or dose (J/cm^2). If power densities and doses are too low they are ineffective and if too high they are damaging. *In vivo*, more parameters enter the picture, modifying this window. For example, the depth of the target injury affects how much energy must be applied at the surface because the intervening tissue will absorb some of the energy. The deeper the tissue, the more the energy that must be applied at the surface to ensure that a locally effective dose reaches the target. Phototherapy also produces systemic effects on, for example, the vascular, immune, endocrine and nervous systems which permits it to affect deep targets indirectly without photons actually reaching these targets. The best results are achieved by a combination of local and systemic effects. Sometimes the systemic effects are not considered by investigators; this has led to misinterpretation of the significance of some clinical observations, as described below.

Clinical examples

1. Arthritis

(a) In 1993, Heussler et al ⁸ published a double blind randomized study in which they deduced that near-infrared low intensity (power) lasers were ineffective in the treatment of rheumatoid arthritis at a dose of 12 J/cm² even though 72% of the patients reported pain relief. This analgesia was dismissed by the authors as a powerful placebo effect, in part because pain relief was reported in both the treated and untreated hand. Similar bilateral effects have been found in many clinical investigations and in wound healing studies conducted on animals. It is now appreciated that phototherapy produces both local and systemic effects on the vascular, immunological, endocrinological and nervous systems; these systemic effects may help to explain how bilateral improvements can occur. In the light of this the deduction of ineffectiveness is can be seen to be incorrect.

(b) In 1992 Stelian et al ⁹ published a study reporting that low-power light therapy was effective in relieving pain and disability in degenerative osteoarthritis of the knee. In this study, red and near infrared lasers with intensities in the milliwatt range were used at doses of 5-6 J/cm².

(c) In 2000, Brosseau et al ¹⁰ published a meta-analysis of the effects of low level laser therapy on osteoarthritis and rheumatoid arthritis. They concluded that for rheumatoid arthritis low level laser therapy 'should be considered for short term relief of pain and morning stiffness since it has few side effects'. For osteoarthritis it was concluded that the results were conflicting and 'may depend on the method of application and other features of the low level laser therapy.

2. Carpal tunnel syndrome

In March 2007 Elwakil et al ¹¹ reported a comparison of low LLLT (632 nm, 12 mW, 3 J/cm², 12 biweekly treatments) with open carpal tunnel release surgery. Their conclusion after a 6 month follow-up was that LLLT had 'proven to be effective and noninvasive for early and mild-to-moderate cases where pain is the main presenting symptom, whereas as surgery could be reserved for advanced and chronic cases'. We suggest that surgery be followed by phototherapy as soon as possible to resolve the inflammatory phase of the repair process initiated by the surgery and to relieve the acute pain associated with it.

Phototherapy devices

These consist of either single emitters or clusters of emitters. The most popular emitters are semiconductor diodes based on gallium-aluminium-arsenide (GaAlAs). Single probes emit monochromatic radiation. A cluster probe consists of several emitters of either the same or several different electromagnetic wavelengths. Modern LLLT devices are patient friendly and easy to operate. Many are portable. As with all laser devices, both the person using the laser and the patient should wear eye protection (goggles) when the device is in use.

How to apply phototherapy

When treating an open wound LLLT can be applied through a transparent dressing such as Opsite or Tegaderm; there is no need to remove such dressings prior to treatment. However if the dressing is opaque, it must be removed. The probe can either be placed in contact with the dressing or held just above it. Mester et al (1985)⁴ recommended the use of an energy density of 4 J/cm². In addition to treating the wound bed, Baxter (2002)² recommends treating the intact skin around the wound with a single probe at points about 1- 2 cm from the wound margin and about 2-3 cm apart. Tuner and Hode (2002)¹ recommend treating the open wound with a dosage of 0.5 J/cm² and the skin next to the wound with 3-4 J/cm². The probe can be placed on the surface of intact skin when treating deep injuries.

Single probes can be used to treat acupuncture points and trigger points.

CONCLUSIONS

- Phototherapy can relieve pain and can help injuries heal.
- Inflammation is resolved more rapidly than in injuries not treated with it and the proliferative phase of healing begins earlier.
- Ideally, phototherapy should be applied as soon as possible after injury or infection so that chronic conditions are avoided.
- Both local and systemic effects are induced by phototherapy
- More investigations are needed to find the best treatment parameters. These parameters will vary with the clinical status of the patient.

We recommend that more pain practitioners have access to training in phototherapy. The quality of life of more patients would be improved, and time and money saved, by replacing less effective pharmaceutical treatment and unnecessary surgery with phototherapy.

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