COLD LASERS IN PAIN MANAGEMENT

Low energy laser therapy has been shown — at appropriate dosimetry, wavelength, duration, and site-specific application — to reduce tissue pain/tenderness, normalize circulation patterns in tissue trauma, and increase collagen formation in wounds.

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Cold or soft laser therapy, also know as low level laser therapy (LLLT), is being used for an increasing number of medical and rehabilitative applications including pain management. The nomenclature alludes to the athermic or non heat producing characteristic of these FDA class 2 and 3 devices.[1] Unlike hot lasers used to cauterize, vaporize, coagulate, or ablate tissue or tumors, cold lasers work through more subtle tissue effects that can result in the reduction of both pain and inflammation, devoid of tissue destruction. Consequently, cold lasers are finding a niche with soft tissue specialists of varying backgrounds including medicine, podiatry, dentistry and physical rehabilitation. Although a relatively new modality in the United States, cold lasers have been used in Canada, Europe and some parts of Asia for many years. Lasers fall under the general category of photomedicine, but this broader name often obscures the unique properties inherent with laser, properties which serve to distinguish this form of light therapy from other, perhaps less potent, forms of light energy.

In 2002, the FDA issued the first 510k premarket notification for a soft or cold laser device based largely on the strength of earlier large scale multi center clinical trials that had examined the effectiveness of cold lasers in the primary treatment of carpal tunnel syndrome. The GM study, as it has come to be known by, was arguably, the pivotal investigation that "tipped" the scale in favor of FDA approval for these devices. Since then, a number of laser manufacturers have followed suit with their versions of the ideal lasing device. To date, all these devices have been under a specified power level of 1 watt (considered to be threshold for thermal effect) and usually between 5 and 100mW. As a point of reference, a laser pointer is approximately 2-3mW in power. Recently, FDA class 4 devices have been introduced into the marketplace with much higher average power levels than their class 2 and 3 counterparts. Typically seen in veterinary medical use, time will tell how these devices will add clinical utility to the already growing number of lasers in the marketplace.

While numerous studies utilizing cold lasers have been performed to date, many do not provide precise test parameters such as power density, treatment duration, wavelength and site of application — all essential information needed to replicate findings. Despite the currently limited amount of quality research supporting cold laser use, the number of double blinded, randomized and controlled clinical trials is growing, as well as the amount of empirical evidence gathered from the now daily use of these instruments across the country.

Laser-Tissue Interaction

The two most important modes of light interaction with tissue during laser treatment is through absorption and scattering. This has been studied predominantly at the molecular and macro-molecular level. Absorption is considered to be a conversion of energy from light to another form. Tissue absorbing properties are dependent on their concentration of light accepting molecules such as amino acids, cytochromes, chromophores and water. Each of these interacts with light at specific wavelength ranges (bandwidths). Scattering also occurs during cold laser treatment and is considered to be a change in light propagation direction and thought to occur due to the varying shapes of biomolecules and varying tissue interface configurations. Depth of penetration is determined by tissue type and wavelength emitted by a laser system. Like other forms of energy used in clinical settings such as electricity, heat, and sound, there is significant energy attenuation of laser light as it passes through tissues. The critical measurement in laser dosimetry appears to be energy density, which is calculated by dividing the total energy delivered to an area by the area of irradiation and expressed as joules per centimeter squared (J/cm^2).[2] Among other lasing characteristics, the energy density should always be reported in clinical studies so replication is possible. Animal studies have typically cited radiant exposure levels of 3-4J/cm^2, whereas in human studies, it is recommended that significantly higher levels of irradiation approximating 30J/cm^2 are required to compensate for animal size and skin type differences.[3]

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Clinical Applications of Low Level Laser Therapy

Arthritis. The arthritides (osteo and rheumatoid forms) have been a popular target disorder for researchers in the last decade of cold laser investigations. The results of several well designed randomized clinical trials have given clinicians good reason to be encouraged with this form of treatment. Cellular research has provided some possible mechanisms of action for these positive results including laser mediated increases in cellular proliferation,[4] enhanced collagen synthesis,[5] conversion of fibroblasts into myofibroblasts,[6] increased osteoclastic activity,[7] reduced inflammatory markers,[8] increased lymphocyte response[9] and stimulation of the electron transport system leading to enhanced ATP production.[10] These putative mechanisms help explain the impressive results that laser therapy research has had to date in the area of wound healing. With the use of larger diameter cluster probes emitting beams of mixed wavelengths, clinicians can efficiently treat large wounds in short periods of time. Brosseau et al conducted a systematic review of the available literature examining the relationship between low level laser and arthritis in 2000.[11] They applied an a priori protocol according to methods recommended by the Cochrane Collaboration. Their conclusions were that low level laser therapy (LLLT) should be considered for short term relief of pain and morning stiffness in rheumatoid arthritis. In regards to osteoarthritis, the same authors felt that a determination of effectiveness could not be made based on the available literature due to conflicting and lacking consistent dosage descriptors. The general consensus among clinicians using LLLT for conditions having an inflammatory component is that significant benefits can be accrued by those patients treated with laser. There have been some very promising clinical trials involving cold laser in both knee and cervical spine osteoarthritis as well.[12,13]

Carpal Tunnel Syndrome. Although not as studied a clinical condition as other pathologies, this landmark cold laser investigation occurred at the Flint, Michigan GM plant when Anderson et al studied the effects of cold laser on carpal tunnel syndrome (CTS).[14] In this particular study involving 119 subjects, half received sham laser plus physical therapy while the treatment group received real laser plus physical therapy. The results of this randomized,controlled and double blinded study were that there was a statistically significant treatment effect shown by the real laser group, furthermore, the authors stated that low level laser therapy combined with physical therapy (strengthening, ROM etc) improves functional measures of wrist-hand work performance and results in greater probability of return to work. Since that study was completed, others have followed with similar confirmations of lasers potential efficacy in the treatment of this insidious and economically costly occupational disease known as CTS. Dosages described by various investigators range from 2-10 joules of energy per point per treatment session with several key points usually comprising the total treatment area. As an example, Weintraub reports using 9 joules of energy over 5 points per session with a treatment course ranging from 7 to 15 sessions depending on individual patient response.[15] Balmes et al applied a 5J/cm^2 (energy density) dosage schedule to their patient sample (n=33) and found beneficial results as measured by sensory distal latency on EMG.[16]

Myofascial Pain and Trigger Points. The application of cold laser to myofascial syndromes is very common among photobiology specialists. These seemingly innocuous but sometimes debilitating tender and painful areas can be a cause for concern for many patients. There have been numerous therapies and treatments expounded for their TP eradication properties stemming from pharmacotherapy and injections to acupuncture and positional release techniques. Numerous studies have supported the benefits of cold laser application for musculo-skeletal pain and dysfunction caused by trigger points, a common source of localized myalgic pain. Laasko et al published a randomized, double blinded, placebo controlled clinical trial involving 41 patients with confirmed trigger points in the upper extremities.[17] His treatment regimen included each subject receiving 5 treatment sessions (twice daily) using both a near infra-red (670nm) of 10mW average power and a far infra-red unit (820nm) of 25mW average power level. A total of 1 and 5J/cm^2 respectively were used by these investigators. Their results supported a positive treatment response with both wavelengths, however the 820nm laser provided the greatest treatment effect.

Simonovic et al studied 243 subjects with confirmed trigger points and found very similar results with pain, tenderness, local muscle tautness, and amount of required pain medication all reducing significantly in his patient population sample.[18] They used virtually identical wavelengths as Laasko et al including a helium-neon 632.8nm and an infra-red 820nm unit. They found that pain decreased by over 70% and concluded by endorsing LLLT as either an effective monotherapy and/or a very important adjunct.

These findings simply confirmed what was originally found in 1986 when one of the first studies examining the effectiveness of LLLT on the trigger point phenomenon appeared in the Journal of Physical Therapy. Snyder-Mackler et al reported that LLLT, even at what is recognized today as being at very low dosage (J/cm^2), was effective in reducing pain and tenderness in their small sample group.[19] This group of investigators utilized a relatively low powered helium neon laser with supposed minimal penetration capabilities and what we know today is optimally designed for more superficial scanning such as in decubitus ulcers and/or post injury tissue necrosis.

Subsequent studies seem to support the idea that laser therapy not only reduces pain/tenderness but may also act to normalize disrupted circulation patterns inherent in tissue trauma. Several studies have alluded to a noticeable temperature "adjusting" mechanism when LLLT has been used. In acute conditions Asagai et al noted that there was a noticeable cooling effect in the "hot zone" of an injury post laser application where inflammation was most pronounced.[20] In contrast, the "peripheral zone" in injury, which is typically of lower temperature during inflammation, was seen to gradually rise by the same amount as the hot zone dropped (approximately 3C degrees) post lasing. The authors noted that consistent with these vascular changes confirmed by thermography, there was concurrent reduction in clinical signs of swelling/edema as well. In the treatment of chronic pain, Fukuuchi et al, using a higher power GaAlAs (semiconductor) laser with output of 100mW at a wavelength of 810nm, found that skin temperature rose significantly in the treatment group and not at all in the sham control group.[21] Furthermore, 75% of the treatment group demonstrated improvement in pain and tenderness levels while only 4% of the control group improved. An increase in tissue temperature is an unusual finding given that soft or cold lasers are named as such for their non thermal effects. These positive outcome results are similar to those of Salansky et al who also showed that when laser was added to a treatment regimen consisting of therapeutic exercise and spinal adjustments for treatment of whiplash injury, the therapeutic results are superior than treatment consisting of exercise and spinal adjustments alone.[22]

Dosimetry Note. It is a generally accepted laser principle that the more chronic an area, the greater the energy required to cause a therapeutic effect. Conversely, the more acute the problem, the less energy used to irradiate the region. The amount of treatment time per point will vary depending on the average power rating of the lasing device being used. This is where a more powerful laser has the advantage of being able to saturate an area with light energy at a faster rate leading to considerably shorter treatment duration times. This has implications for clinical efficiencies when treating multiple patients throughout the day. As an applied example, if a clinician intends to irradiate an area with a target dose of 1 joule and we compare 3 different laser power output levels, we find the following; a 1mW laser beam would require 1000 seconds to achieve this dosage, whereas a 10mW laser would require 100 seconds, and a 50mW laser approximately 20 seconds to make dosage. If the target dose is closer to 10 joules of energy, we can see that these irradiation times are multiplied by a factor of 10. If we are treating multiple trigger points (5-6) we now further multiply the total time by 5 or 6 times. It is this scenario that has laser manufacturer's scrambling to develop more powerful laser systems.

Laser frequencies are often a point of discussion and debate as they relate to cold laser application. There are many manuals in existence written for the most part, anecdotally, whereby

LASER PROPERTIES AND CHARACTERISTICS

There are three essential components to a laser system, those being; a lasing medium, an energy source, and the mechanical structure of the laser. We will confine this discussion to cold lasers in the near to far infra-red range of the electromagnetic spectra (visible red to invisible red). The lasing medium is a material which is capable of being excited by an outside source and absorbing that energy produced when electrons are excited from one level to another. Lasing media can be gaseous, liquid, solid crystal or semiconductor in nature. Helium-neon is an example of a gas medium laser while gallium aluminum arsenide is an example of a semiconductor medium laser. The selection of the lasing medium is important since this will dictate the wavelength of the device's output and ultimately determine the color of the beam and depth of penetration.

The energy source is the next component that needs description however, invariably the energy source most common to systems used in pain management will be electrical power. Lasers operating in the 632 (visible red) to 1000nm (far infra-red) wavelength and used to treat pain and myofascial syndromes will typically be driven by a local main power supply.

Early therapeutic lasers utilized two wavelength specific mirrors mounted parallel to each other and a fixed distance from each other (a multiple of the lasers wavelength) so as to reflect only a certain wavelength range. This mechanical structure holds true today for many lasers except those using semiconductor technology. These units use polished diodes and special lenses to both selectively emit and concentrate the laser beam consisting of light particles or photons.

Laser light distinguishes itself from other forms of light in that it is monochromatic, directional and coherent. The spectral emission (bandwidth) from a laser is much more limited than other sources of light such as incandescent or flourescent light. Lasers emit at specific wavelengths such as 632nm (helium-neon laser) whereas, by comparison, an infra-red lamp emits many wavelengths within the infra-red spectral range (multiple wavelengths). This becomes important as wavelength becomes the primary determinant of depth of penetration. The term collimation refers to a laser's high degree of beam parallelity and is the opposite of beam divergence. This becomes clinically important since the greater the divergence, the larger the spot size for treatment and the lower the power density. A more focused beam increases the power density and also increases the ocular hazard for both operator and patient. To minimize losses in power, the laser should be kept as close to the target tissue as possible. It is important to note that non laser sources of light scatter light at many wavelengths in different directions, in stark contrast to laser light which is focused almost perfectly parallel and in one direction. Finally, a laser is said to have coherence, a property whose biological significance has been debated by researchers. Coherence suggests a synchronicity in light waves so that each wave maintains a precise spatial relationship with other waves and that this pattern is maintained over long distances. Having said this, there is a trend towards manufacturing superluminous diodes (SLDs) which are highly monochromatic and collimated, but not coherent sources of light. This translates to a less expensive, and cheaper manufacturing process while retaining many of the true laser's desired qualities.[35]

authors passionately make an argument for the importance of frequency modulation (chopping a continuous wave) into various frequency cycle or pulse bursts, sometimes altering the pulse amplitude, width, and interpulse interval. Whether there is strong evidence at this time that a pulsing frequency affects a specific clinical condition is not clear. That is not to say that future research will not elucidate key frequencies as optimal for therapeutic goals. There is in existence an entire library of information that supports the physics of frequencies in general (sound, light, electrical etc) as being important in achieving certain characteristics such as conveying intelligence in radio waves (AM,FM). Authors such as Voll, Nogier and Bahr all wrote about resonance theory and how frequencies transfer kinetic energy to electrically charged cell particles and also can transmit specific information. We know for instance that electromagnetic frequencies in brain research are associated with certain bodily reactions, such as delta waves for deep sleep, and gamma waves in stress. In any case, the role of laser frequencies remains an open area for clinical investigation.

Tendinopathy. There have been numerous reports published that support the beneficial aspects of LLLT in tendon healing through laser's positive effects on collagen tissue. Enwemeka et al reported that several laser types including HeNe, GaAs, and GaAlAs all promoted beneficial effects on tendon healing when combined with ultrasound and early weight bearing, over those of ultrasound and early weight bearing, together or in isolation, without laser.[23] The authors noted improvements in biochemical, biomechanical and morphological indices of tendon healing. A clinical study using 176 patients with tendonitis conducted by Logdberg-Andersson et al found that laser application significantly reduced the morbidity associated with acute tendonitis over a 6 session treatment course.[24] Similar findings were corroborated by Bjordal et al in 2001,[25] Thomasson,[26] and Hronkova et al.[27] Energy densities ranging between 5 and 20J/cm^2 and wavelengths above 800nm are recommended for deeper penetration capabilities. No more specific dosage recommendations can be provided at this time since more research is required to elucidate more precise dosages. Practitioners who treat facial points for conditions such as neuralgias or TMJ syndrome will irradiate at dosages approximating 1-5J/cm^2 and may experience success with either HeNe or deeper penetrating lasers such as GaAlAs.

Laser practitioners also apply this mode of treatment to various forms of tendinopathy including medial and lateral epicondylitis, plantar fascitis, rotator cuff and various other enthesopathies. All these conditions have been studied using laser as the primary form of treatment with varying degrees of success. There is such a wide variation in treatment response noted in these studies which is consistent with the wide array of dosage parameters used, not to mention wavelength choice, which is crucial for proper penetration depth. The majority of "no difference" trials have used a helium-neon laser source which has the least penetration power of any laser coupled with low power density capability. The end result is a negligible energy density and not a high probability of a therapeutic effect. Unfortunately, many clinical trials have been accidentally undermined from the start with poor dosage selection parameters. Investigations utilizing higher energy densities (>3J/cm^2) were more likely to show a statistically significant difference between treatment and control groups.

Wound Healing. There is considerably more and better research support for the use of cold laser application in wound healing perhaps than any other medical condition discussed so far. In 2004, Woodruff et al published a meta-analysis on the subject and concluded that laser therapy is an effective tool for promoting wound repair.[28] This conclusion draws support from many others who have investigated the use of laser in wound healing. One of the primary laser mediated physiological benefits to a wound is that a laser will increase the amount of collagen formation in the irradiated region. Laser has demonstrated to have positive effects on both macrophage and fibroblast cell lines.[29] A more recent finding has been that certain laser wavelengths, such as the 630nm (helium-neon), has an inhibitory effect on certain bacterial strains including E. coli.[30] This has valuable implications for the treatment of infected wounds. There have been quite a number of significant in vitro and in vivo findings as they pertain to cold laser usage that would help explain many of the empirical or observational reports that are pervasive in the literature today. Nicola et al found that laser biostimulation of rat femurs over the course of 8 days using a 660nm wavelength and dosing the lasing site at 10J/cm^2 had a positive effect on bone cell activity, both resorption and formation, around the site of repair without changing bone structure.[31] Similar findings were reported by other researchers who also reported increased trabecular bone growth, along with a hastened collagen matrix organization.[7] Other cell lines including mogenic types including muscle satellite cells have also been shown to be affected by LLLT, specifically laser's ability to increase the number of satellite cells around isolated single muscle fibers.[32] These findings are bolstered by the NASA studies on light emitting diodes (LEDs) as reported by Whelan et al concluding that light therapy has been found to increase fibroblasts, osteoblasts, skeletal muscle cells and human epithelial cells.[33] Their work was performed primarily on rodents but the authors feel that it is only a matter of time before similar findings are corroborated in human studies.

A special note regarding the role of NASA in laser research would be appropriate given the scope and magnitude of this agency's contribution to the role of light therapy thus far. Studies on cells exposed to varying levels of gravity have concluded that human cells require gravity to stimulate growth. This requirement poses significant challenge to those astronauts involved in long term space flight. NASA developed LEDs as a way in which to stimulate the basic but essential mitochondrial processes of each cell so as to provide not only tissue healing, but also to minimize bone and muscle atrophy. NASA views LED technology as a promising alternative to medication and surgery whereby the biostimulation of natural regenerative mechanisms would be the primary goal. In regards to wound healing, the NASA project has demonstrated that wavelengths between 670 and 880nm at total energy levels of 4-8J/cm^2 applied at power densities of 50mW/cm^2 are optimal parameters.[34]

Conclusion

There continues to be a pressing need for properly controlled randomized clinical trials in the field of laser therapy. It is not difficult to see that these devices could im-

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part a powerful placebo effect in even the most skeptical patient. The research base regarding lasers is only as good as the methods and designs implemented in the individual trials comprising the base. There is more reason to be optimistic than not however, since more product interest will necessitate an increased push for better research validation. Those practitioners who have used cold lasers on a regular basis will in many cases remark that "absence of evidence is not evidence of absence." I would have to agree in the case of cold laser. For the most part, many of the authors who published manuscripts that found "no difference" between control and treatment groups have stated in their conclusion that more research is recommended, and furthermore, more research is warranted. The in-vitro and in-vivo studies clearly have demonstrated that dose and wavelength are critical in achieving therapeutic goals, yet many reports fail to fully describe both parameters. This is not a failure of the modality under study, it is a flaw in the study design. Cold lasers are slowly working their way to becoming commonly used therapeutic modalities of choice in the treatment of painful conditions of musculoskeletal origin. More work needs to be done in elucidating human dose-response relationships and condition-specific optimal wavelength selection. Ultimately, it will be the day to day performance of cold lasers on patient problems that will have the most impact in deciding the clinical place cold lasers will occupy in the therapeutic milieu, quite apart from the research support. From this perspective, the introduction of cold laser into the field of pain management could supercede the growth pattern of many of our more contemporary modalities. ■

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