

DOSE DILEMMAS IN LOW LEVEL LASER THERAPY - THE EFFECTS OF DIFFERENT PARADIGMS AND HISTORICAL PERSPECTIVES.

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Low Level Laser Therapy (LLLT) is controversial because of conflicting outcomes in peer reviewed literature. The possible combination and permutation of laser parameters is almost infinite. Defining what is an appropriate dose of laser energy for anyone condition remains anecdotal. A number of factors have contributed to the heterogeneity of the literature and the variable outcomes. This paper examines how the confusion between laser acupuncture and non-acupuncture laser therapy has added to the dose dilemmas faced by clinicians using LLLT. Both historical and scientific perspectives on these differences are used to compare these two paradigms of laser therapy. An understanding of these differences may foster a more rational development of LLLT protocols.

Keywords: Laser Acupuncture, Laser Therapy

Introduction

Low Level Laser Therapy has yet to gain wide acceptance in the medical community. The evidence base remains inconclusive to many in the medical profession though as Basford points out " laser therapy has shown a tenacious ability to weather disbelief and lack of knowledge [1].

Systematic reviews such as the Cochrane Review suggest that, because there are so many different parameters in laser therapy, it is difficult to evaluate the literature [2]. The lack of reporting by authors of many of the critical parameters of the laser device makes an assessment of the appropriate dose of laser delivered extremely difficult. Defining the appropriate dose of laser in the treatment of any given condition is still anecdotal rather than based on evidence. Even "experts" cannot agree on appropriate parameters for laser therapy or how to interpret the literature. Fundamental flaws in reviews have occurred because of the failure to appreciate these complexities [3]. The complexity is increased by the different ways in which laser is administered, from scanning to pressure point contact. Adding to the confusion is the application of laser in acupuncture point stimulation in contrast to its use in other forms of Low Level Laser Therapy (LLLT). This paper aims to illustrate some of the complexities in understanding the principles of dosing with laser and, in particular, how the use of laser in acupuncture has influenced these concepts. There has been a failure to recognise that laser acupuncture and LLLT are two different paradigms which require different approaches and doses. This has been one of the factors leading to confusion in treatment application and outcomes.

Laser Acupuncture compared with Laser Therapy

Laser acupuncture was developed as a way of stimulating acupuncture points without the obvious disadvantages and attendant risks of skin penetration [4]. It relies on the stimulation of anatomically defined points on the surface of the body which appear to have specific properties. It is postulated that, when stimulated, these points initiate a specific cascade of neurophysiological responses in the central nervous system, producing an alteration in efferent output and resulting in the amelioration of pain and other symptoms [5]. Whether laser stimulation of acupuncture points produces the same effects as needle acupuncture has been the subject of much research [6, 7]. There is conflicting evidence about the mechanisms of action of laser acupuncture, with some research suggesting that the same pathways are stimulated as with needles [8]. Other evidence suggests that pathways of action of laser acupuncture may be different from that of needle acupuncture [9]. One of the mechanisms proposed for the effects of needle acupuncture is the stimulation of endorphin production. Other mechanisms include stimulation of descending noxious inhibitory control pathways in the spinal cord, spinal reflex pathways, and/or serotonin and nor-adrenalin release [10]. Needle acupuncture is blocked by Naloxone, but does not appear to block laser acupuncture induced analgesia. The fact that laser induced analgesia is not blocked by Naloxone suggests that other mechanisms may be operating. [11].

Non-acupuncture laser therapy, on the other hand, relies to a large extent, on the local effects of light on tissue with-

out the stimulation of specific neurophysiological pathways. These actions of laser *in vitro* are the subject of many hundreds of papers and include anti-inflammatory action [12] stimulation of lymph vessels [13], stimulation of cell growth [14], and changes in the distal latency of nerves [15]. There is also a postulated systemic effect of laser therapy and this is used in a variety of clinical conditions [16]. How this is mediated and the true extent of this effect is much less clear as there is a dearth of information in this area.

There are several critical differences between these two applications of laser which may have contributed to the way doses of laser have been derived.

General dosing principles

In general the correct dose of laser is that which delivers the optimal amount of energy in joules, at a particular energy density and specific power density to the correct site, using the appropriate wavelength for the condition being treated. As yet, there is no consensus on what this is for any one condition using all the parameters outlined.

What appears as a constant from the vast majority of papers associated with wound healing and stimulation of cell cultures is the use of energy densities with a range of 1- 4J/cm² [17]. This is regarded as the range in which laser induces biostimulation, in contrast to bioinhibition, which is said to occur at energy densities above that. If 1-4J/cm² is the "correct" range of incident energy density at the target tissue for biostimulation, which appears to be supported by the literature, this should be generalisable to all situations where laser is being used.

The stimulation of superficial tissues, such as those in chronic ulcers or cell cultures, with low power lasers, delivering energy densities in the range of 1- 4J/cm², is easily attainable. Even in these conditions, however, results are still equivocal and other factors are likely to be operative [18]. The ability to deliver energy densities in this range for deeper structures becomes problematic, especially when low power lasers in the range of 5 to 10mW used. The drop in energy density deeper into the tissue is due to exponential attenuation as demonstrated by various models [19]. This attenuation of energy density *in vivo* and the need to achieve biostimulatory doses of lasers in deeper tissues for many painful conditions, is the basis for the discrepancy between laser acupuncture and non-acupuncture laser therapy models of treatment. This difference may cause confusion with regard to the use of appropriate doses.

Doses in laser acupuncture

Acupuncture points are generally superficial though there

are some deep acupuncture points in the gluteal muscles as well as other large muscles. Biostimulatory doses of laser are able to reach the superficial points and cause the cascade of neurophysiological events that characterize acupuncture. In the meridian system of acupuncture, there are multiple linkages and pathways, through the superficial meridian systems, where, hypothetically at least, one can describe mechanisms by which superficial stimulation in the skin can affect much deeper structures [20]. The principle by which these very low doses of lasers can cause a strong physiological response is known as the Arndt-Schultz law. This states that small amounts of energy are biostimulatory and high doses are inhibitory [19].

Many practitioners trained in acupuncture are taught to use lasers at these very low doses. Characteristically these practitioners use laser devices of very low power, often no more than 10mW. They use predominantly visible laser for short periods of time, between 15 and 20 seconds. These practitioners generally do not think in terms of joules, energy density or power density. In practice, dose is measured in seconds per point in any clinical setting.

Doses in non-acupuncture laser therapy

In contrast, many practitioners who use non-acupuncture laser therapy do so without any training in acupuncture. Essentially, in these situations, non-acupuncture laser therapy relies on the application of the laser beam, either by contact technique or scanning technique, to anatomical sites, such as muscle bellies, tendons, joints or along the distribution of nerves. In these situations, to achieve an energy density of laser in the range of 1-4J/cm² at the target tissue, requires a much higher incident energy on the skin surface. If this is not achieved then it is likely that the desired physiological change in the tissue will not occur. It can be seen from a number of studies that the appropriate energy density for biostimulation at the target tissue can never be achieved with the incident energy densities at the surface of the skin being very low [21].

Comparison of laser acupuncture and non-acupuncture laser therapy

Differences in application between these two paradigms can be further elaborated upon. It can be postulated that laser acupuncture entails an "on and off" mechanism. It stimulates an acupuncture point on a particular nerve tract which has a defined pathway and a defined set of responses. Once the acupuncture stimulus is switched on the processes that perpetuate the response come into play with c-fos gene replication [22]. The implication here is that once the acupuncture point is stimulated appropriately, over a short period of time measured in seconds,

there is no point in stimulating it further. There is a very narrow dose response curve. In contrast, with non-acupuncture laser therapy there appears to be a much broader dose response curve up to a maximum level beyond which the bioinhibitory forces are postulated to be activated. In general larger doses are necessary to achieve the desired effects on the tissues in non-acupuncture laser therapy, compared with the smaller doses for laser acupuncture.

Very accurate point location is necessary with laser acupuncture. There is usually no sensation to help determine whether or not a point has been stimulated with laser as it is with needle acupuncture. Therefore, the location and choice of point is crucial to the success of the treatment. Also, in contrast, with non-acupuncture laser therapy the area over which the laser is used is often more extensive.

Table 1 - Summary of differences between laser acupuncture and non-acupuncture laser therapy

Laser Acupuncture	Laser Therapy
Very low doses of laser	“Higher” doses required
Low powers used e.g. 1.5mW	“Higher” powers used eg 100mW
Uses acupuncture pathways	Relies on direct effects of laser on tissues
Superficial tissue stimulation.	“deeper” tissues treated
On/off mechanism	Response is dose related
Requires precise point location	Requires Rx of correct anatomical structure

The grey area

Complicating the clearly definable differences of these two paradigms is the grey area of "trigger" points. Trigger points cross both the acupuncture and the non-acupuncture laser therapy paradigms. In acupuncture those points which cause a patient to withdraw or respond with an exclamation of pain, depending on the language of the patient, are called "Ah Shi" points or "Ah yes!" points. Whether these are the "trigger points" of Travell and Simons is a moot point [23]. In practice they may be treated with either type of laser therapy. There are a number of

trials evaluating the effect of laser on trigger points. They are generally treated with the lower "doses" of laser and a number of trials show a positive effect [24, 25]. The question remains as to whether this is laser acupuncture or non-acupuncture laser therapy. In addition, it is said that 80% of acupuncture points are tender points [23]. If this is true then it is likely that, if tender points are being treated, then acupuncture points are being stimulated whether the practitioner is aware of this or not. This is a theoretical consideration and may or may not have relevance in the context of doses. It poses the question, though, as to whether treating trigger points with laser entails using laser acupuncture or non-acupuncture laser therapy, and whether it is likely that a different result will be achieved if a smaller or larger "dose" of laser is used.

Historical issues influencing doses

There is an historical perspective on the use of the lower dose lasers which is relevant to the discussion. When the use of lasers in clinical medicine began laser devices being developed were in the lower power ranges eg 1.5 to 10mW. These were appropriate for laser acupuncture point stimulation. The work in wound healing and on cell cultures also used laser devices with this range of power. Energy densities in the range of 1-4J/cm² became an entrenched concept without consideration for the many other factors operating in a clinical setting including target tissue depth.

Practitioners also started to use lasers without an acupuncture background and many of the laser manufacturers' manuals, the major source of information about the use of laser for most practitioners, had protocols which were based on acupuncture models. Practitioners continued to use the lower power lasers where higher doses would have been more appropriate. As is stated by Baxter [19] "HeNe lasers have been the single most popular laser with almost half of all published studies reporting the use of these devices.....The relative lack of penetration with such sources may have played a part in the apparent failure of non-acupuncture laser therapy to produce analgesia in these cases" [19]. This is likely to be true in those studies where the site of application is deep. When positive, the effect may be mediated by an acupuncture pathway.

As the availability of higher power lasers occurred over the last few years, the trend has been to use higher power laser devices. Unfortunately there is still research being performed at these inappropriately low dosing levels where acupuncture "doses" are being used instead of non-acupuncture LLLT "doses".

Acupuncture point stimulation at higher doses

If non-acupuncture laser therapy for certain conditions

has failed because the dose of laser used has been too low, what is the implication for treating acupuncture points using higher power laser devices? If the Arndt-Schultz law is operative then low doses stimulate and high doses inhibit. Stimulation of the acupuncture points would seem to be the desirable outcome. However, there are certain situations in acupuncture where it is appropriate to use a technique to "reduce" the activity of a point [20]. It is therefore possible that even where the dose of laser is high there is still a positive outcome achieved. When a needle is used there are various ways of stimulating the needle to achieve these effects. Hypothetically, it would appear that selecting a particular "dose" of laser is one method of imitating the "stimulating" or "reducing" effects of needling though this has yet to be the subject of research.

Another possible effect of using the higher power lasers on acupuncture points, even when the concepts of reducing and stimulating are not invoked, is that of having greater leeway in the precise anatomical location of the point to be treated. Schematically it would appear as below:

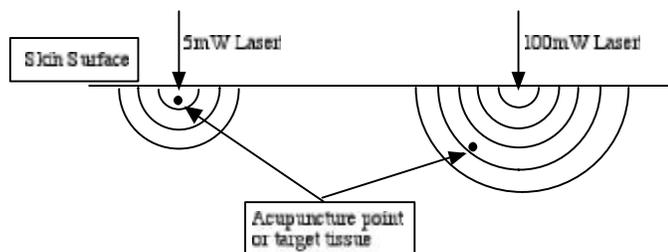


Fig.1

It can be seen that there is more likelihood of a higher power laser "hitting" a target point if the precise point location is not determined. It is much more likely that some stimulation will occur at the periphery of the beam distribution with a higher power beam. This is hypothetical and has not been the subject of research. It would explain some of the anecdotal reports of practitioners having success using laser for stimulation of acupuncture points with both "high" and "low" power lasers.

Non-acupuncture Laser Therapy at higher doses

It is critical that the laser beam reach the target tissue in order to be able to exert an effect, be it an acupuncture point, a specific anatomical structure, or a trigger point. Generally the target tissues are deeper than acupuncture points and a higher dose is required at the skin surface to reach the deeper tissue at a biostimulatory intensity. In addition the angle of application may have relevance to achieving the correct amount of laser energy at the right location. The concept is applicable to the laser reaching the tissue at the correct dose both for acupuncture points as well as deeper anatomical structures and as shown in Figure

1. If the dose, in general, has to be larger at the skin surface than that required for acupuncture point stimulation, then the higher the dose the more likely stimulation will get to the correct structure even if it is not precisely aligned with the beam. This may be one of the reasons that there is disparity in the results of trials.

Doses in the current literature

In comparing and the doses of lasers used, described either as energy density or Joules/point, in randomized clinical trials of laser treatments for painful musculoskeletal conditions, the range of doses can be seen to be enormous (Table 2). It is hard to reconcile these figures without understanding how the laser is applied in these different situations. The assumption is made that these trials are methodologically sound.

It is apparent on examination of the doses used in the positive trials in Table 2 that the dilemma with doses is reinforced. Energy densities range from as low as 0.5J/cm² on trigger points, [32] to as high as 1,800J/cm², [30]. Logdberg-Anderson et al used two different doses, 0.5J/cm² to trigger points and 1J/cm² to deeper anatomical sites. This variation, according to depth of target tissue, is rarely mentioned in other papers. This appears to have no relationship to the 570J/cm² used by Fukuuchi et al 1998 or Toya et al 1994. This raises the possibility that there is a different way of describing energy density, as an average over a square centimeter or as the area under the probe tip of the laser device. The above doses appear to bear very little relationship to the "ideal" dose of 1-4J/cm² at the target tissue which are seen in other studies [33, 25]. It is difficult to make sense of these without the concept of different paradigms operating at the different dose levels. Of interest is the fact that Laasko's work demonstrates no effect of 670nm laser at 5J/cm² but an effect at the lower dose of 1J/cm², both doses being delivered with a 10mW laser. This lends support to the "Arndt-Schultz" law where lower doses stimulate and higher doses inhibit. There is also a suggestion that with the 830nm laser at higher doses there is an effect at both the higher and lower energy densities. This gives weight to the concept that different wavelengths may also be mediated by different photochemical pathways, and producing different effects.

The majority of the studies which are negative, including the acupuncture studies used relatively low doses of laser with energy densities ranging from 1J/cm² to 5J/cm². Siebert et al, 1987, used a dose of 67.5J/cm², (calculated from the data given), with a 904nm laser, but this is applied in a scanning mode from a distance of 10cm from the skin [45]. The target dose at skin level is likely to be much reduced and hence is likely not to be an effective dose. In the study by Basford et al, [21] of non-acupunc-

Table 2: Papers with a positive outcome and doses

Author	Outcome Positive or Type I error	Wavelength	Dose Appropriate	Appropriate Application
Snyder-Mackler et al 1989 Trigger pts {Synder-Mackler 1989}	p<0.005	632.5nm 0.19J/point	dose OK for acupuncture (but target is not acu pt)	possibly
England et al 1989 Shoulder tendinitis ²⁶	p<0.005	904nm(P) pk10W av 3mW;	4.5J/pt @ TP	probably
Umegaki et al 1989 Chr Low Back Pain ²⁷	P<0.01	830nm (CW) 30mW	not assessable	possibly but not described
Ceccherelli et al 1989; cervical myo fasc pain ²⁸	p<0.001	904nm(P) 25W	TPs with 1J/pt & acu pts with 0.1J/pt	yes
Vasseljen et al 1992 lat.epicondylitis ²⁹	p<0.2	904nm (P) pk10W; av 1.5mW	possibly; 3.5J/cm ² ;	probably but inadequately described
Toya et al 1994; chronic pain groups ³⁰	p<0.0001	830nm(CW) 60mW	900 - 1,800J/cm²	probably but inadequately described
Soriano et al 1996 acute neck pain ³¹	p<0.0019	904nm(P) pk: 20W; av.40mW	possibly; 4J/cm ² ; to painful area	probably
Laakso et al 1997 Myo fasc Trigger Pts ²⁵	p<0.001	820nm 25mW	TPs @ 1J/cm ² & 5J/cm ²	yes
Laakso et al 1997 Myo fasc Trigger Pts ²⁵	p<0.01	670nm 10mW	TPs @ 1J//cm ²	yes
Laakso et al 1997 Myo fasc Trigger Pts ²⁵	negative	670nm 10mW	TPs @ 5J//cm ²	probably
Logdberg-Andersson et al 1997 tendonitis; myofas pain ³²	p<0.01 - p<0.001	904nm av 8mW	TPs 0.5J//cm² & anatomical sites 1.0J//cm²	probably
Soriano et al 1998 Chronic Low Back Pain ³³	p<0.01 - p<0.007	904nm(P) peak power 20W av 40mW	4J//cm ² to 2cm grid in area of pain	probably
Fukuuchi et al 1998 Chr Pain ³⁴	p<0.001	810nm(CW) 100mW	4 TPs @ 570J//cm ²	probably
Basford et al 1999 Chronic Low Back Pain ³⁵		1060nm 4 W (CW)	48.78J//cm ² at lumbar spinal muscles	probably

ture laser therapy in plantar fasciitis, the incident energy density used was 0.9J/cm². As the plantar skin is very thick it is highly unlikely that an incident energy density of 0.9J/cm² at the skin would achieve any significant biostimulatory effect in the target tissue. The fact that the laser is not in contact with the skin, can further diminish the amount of photons that reach the target tissue..

In comparing the mode of application between positive and negative studies, there appears to be considerable overlap between methods. It may be hypothesised that dose, and the methods of application are the critical factors affecting the outcomes of these studies.

Conclusion

The aim of this paper is to illustrate some of the intrinsic difficulties with selecting the correct dose in laser therapy. Historical developments in laser technology have naturally influenced the way doses have evolved. The potential confusion that laser acupuncture and LLLT paradigms have added are discussed. The current literature adds to the confusion, given the wide range of doses that seem effective with different situations.

The importance to those who use lasers lies in the need to be clear about the target tissue to be stimulated, how it is stimulated, and the physiological responses expected from

Table 3: Table of negative studies and different doses

Authors	Outcomes- Negative or type I error	Wavelength	Dose Appropriate?	Appropriate application?
Waylonis et al 1988 Chronic Myofasc pain ³⁶	Not statistically significant	632.5nm 0.9mW	possibly 0.015J/pt	probably
Basford et al 1987 OA thumb ³⁷	Not statistically significant	632.5nm 0.9mW	0.015J/ point - no	probably
Rogvi-Hansen B et al 1991 Chondro Mal. Patellae ³⁸	Not statistically significant	904nm(P) 17mW	not enough information to assess	probably
Vecchio et al 1993 Rotator Cuff tenonitis ³⁹	Not statistically significant	830nm 30mW (CW)	3J/pt	probably not
Bulow et al 1994 OA knee ⁴⁰	Not statistically significant	830nm 25mW(CW)	?yes 5-16J//cm ²	possibly
Mulcahy et al 1995; o'paedic problems ⁴¹	Not statistically significant	?nm 35mW	probably not 1J//cm ²	cannot assess; no details
Basford et al 1998 Plantar Fasciitis ²¹	Not statistically significant	830nm 30mW(CW)	probably not 0.99J/pt/area	No
Thorsen et al (1992) neck; shoulder girdle pain ⁴²	Not statistically significant	830nm 30mW(CW)	probably 1.8J/pt	probably
Klein et al 1990 Chronic Low Back Pain ⁴³	Not statistically significant	904nm (P) max output 2W	no 1.3J//cm ²	probably
de Bie et al 1998 ankle sprain ⁴⁴	Not statistically significant	904nm (P) peak 25W	maybe5J//cm ² no 1/Jcm2	no
Siebert et al1987 tendinopathy ⁴⁵	Not statistically significant	632.5/10mW 904nm(P)30mW	no 2.25J/cm ² ?67.5J/ cm ² scan at 10cm	no
Haker et al 1990 lateral epicondylitis ⁴⁶	Not statistically significant	904nm(P) peak 8.3mW av 12mW	0.36/pt @ acu points	possibly too low; no contact of laser with skin
Krasheninni- koff et al 1994 Lat ⁴⁷ epicondylitis	Not statistically significant	830nm(CW) 30mW	3.6J/point	probably

the stimulation. Most of the literature gives little if any attention to this level of complexity in developing standardised doses for particular conditions in the clinical setting. While the 1-4J/cm² remains the "gold standard" for biostimulation, how this dose is achieved at the target tissue needs to be carefully considered. Taking these factors into consideration is more likely to uncover the benefits of laser therapy in a wide range of clinical indications

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