Clinical Applications of Laser Therapy

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Honorary GSTT Laser Consultant

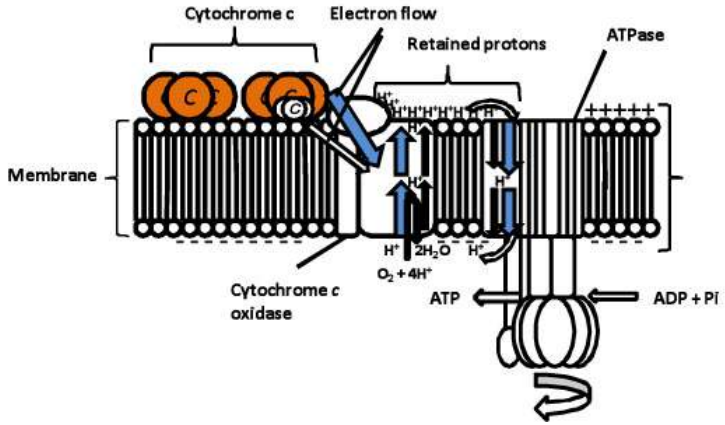
Chromophore: Any component of tissue that absorbs light photons

- The most absorbent *chromophores* in biological tissue are:
  - Water, Melanin, Cytochrome C and Haemoglobin.

Water

Melanin

Cytochrome C



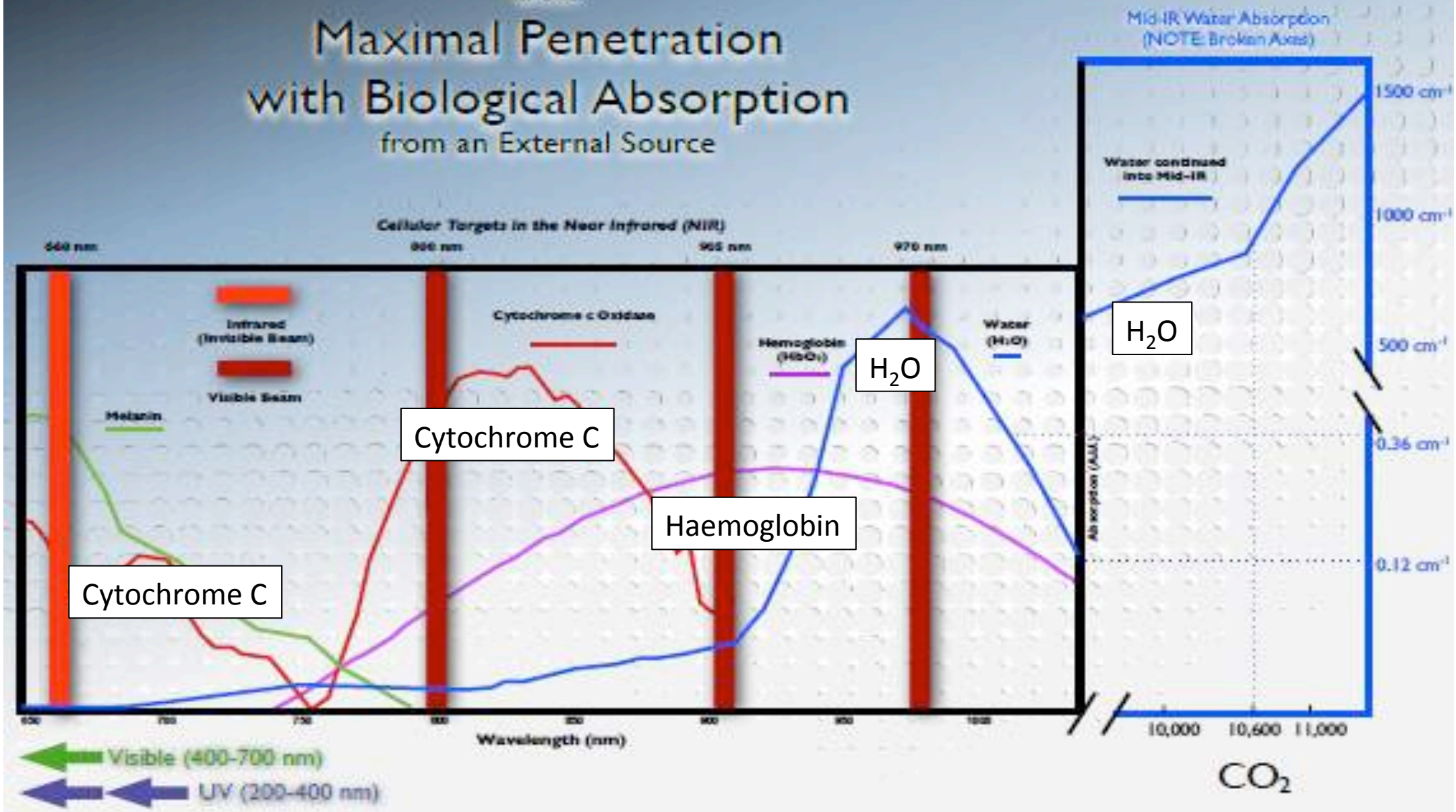
Haemoglobin

Therapeutic Window vs. Surgical Region

Goal:

Maximal Penetration with Biological Absorption

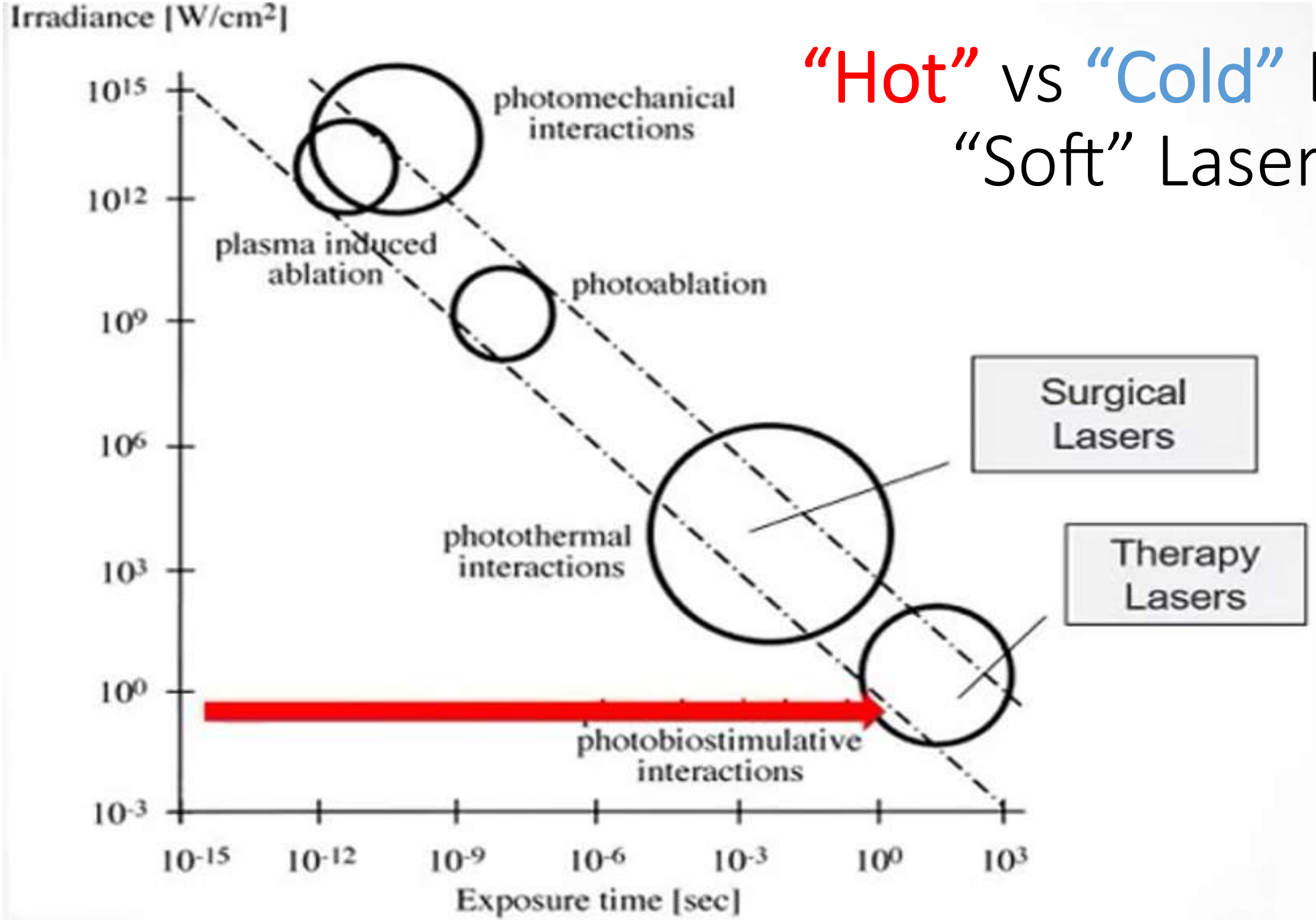
from an External Source



Power Density

- Measured in Watts per square centimeter
- W/cm^2
- Measures concentration of the laser light
- Determines the nature of the laser-tissue interaction, i.e. photothermal, photochemical etc.

"Hot" vs "Cold" Laser
"Soft" Laser

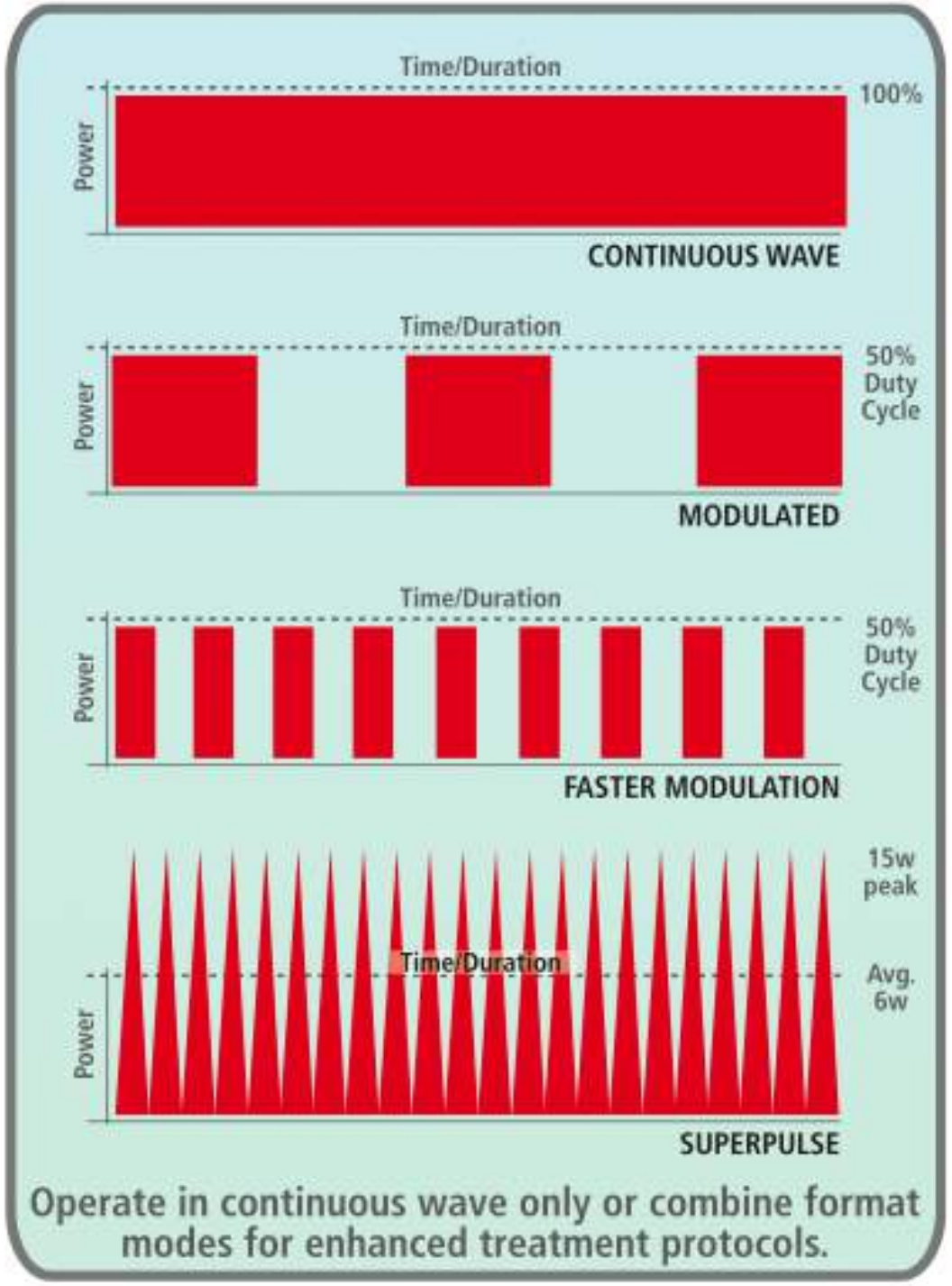


ANSI Laser Standard Classifications

- Class 1: 0-0.4 microwatts (Laser Printer, CD)
- Class 2: 0.4-1.0 mW (pointer, range finder)
- Class 3A:1-5 mW (firearm sights, pointers, therapy)
- Class 3B:5-500 mW (light shows, spectrometry, therapy)
- Class 4: > 500mW (surgery, industry, therapy)

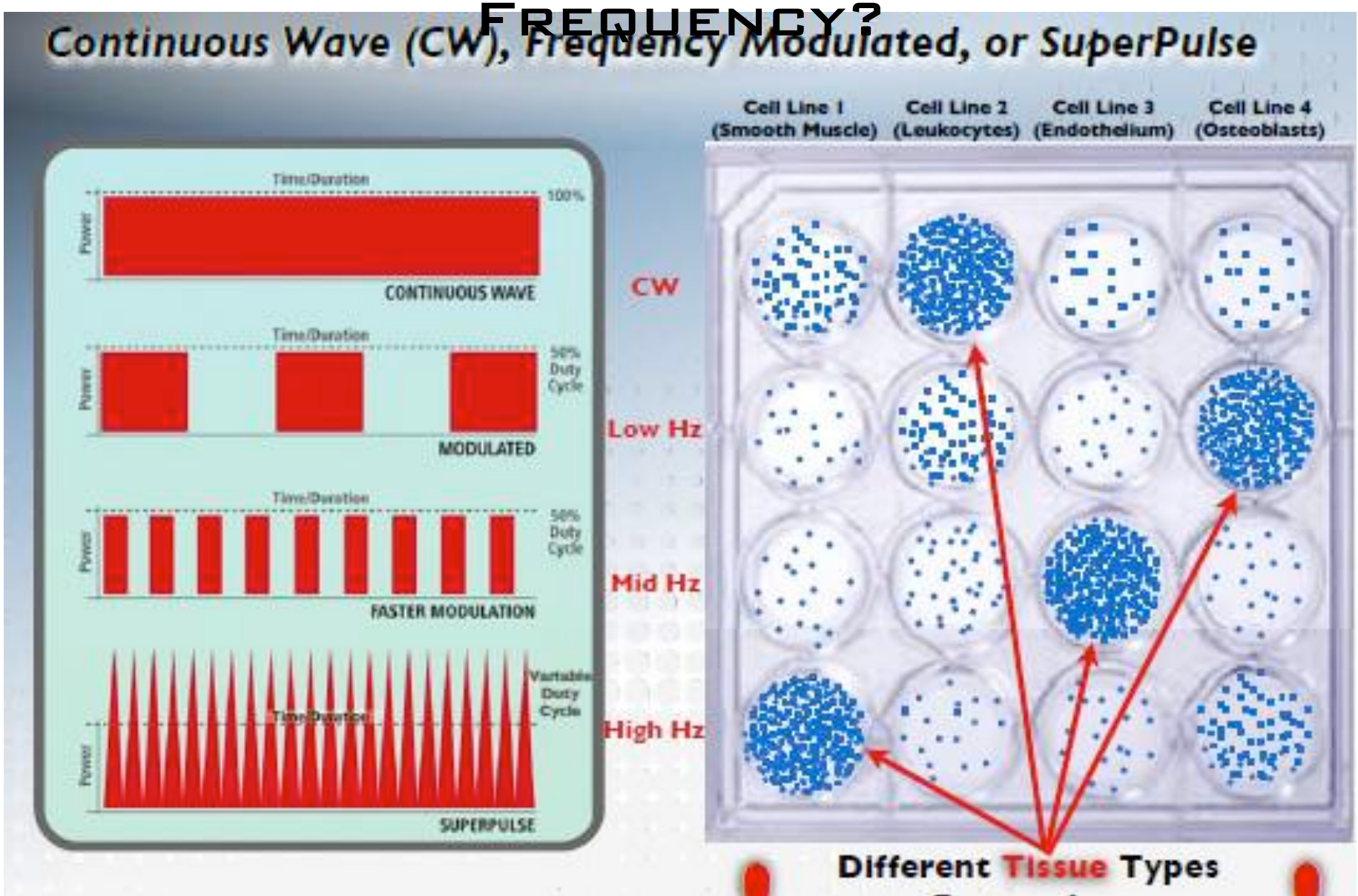
Three Laser Delivery Modes

- Continuous Wave (CW)
  - 0.1 to 18 Watts
- Frequency Modulation
  - 1 – 20,000 Hz
  - Pulse frequency
- Intense SuperPulse
  - 12-20 Watt Peak Power
  - Average up to 6-12 watts



What Do We Know Regarding Pulse Frequency?

What Do We Know Regarding Pulse Frequency?



Clinical Applications

MUSCULOSKELETAL CONDITIONS

Laser therapy penetrates deep into soft tissues, joints and bones, it provides energy to the cells enhancing the natural regenerative processes. By accelerating tissue metabolism and microcirculation, cells assimilate nutrients and get rid of waste and inflammatory products more efficiently. As a result tendons, ligaments and muscles repair faster, with less scarring and reduced pain and inflammation.

- Repetitive strain injuries
- Neck and back pain
- Osteoarthritic joint pain
- Acute and sport injuries
- Musculoskeletal conditions post-pregnancy
- Post-surgical rehabilitation
- And many more disorders

Clinical Applications

PAIN MANAGEMENT

Laser therapy regulates nerve activity, improving functionality in damaged nerve cells, altering nerve pain perception, and reducing local inflammatory processes.

- Osteoarthritic pain
- Neck and back pain
- Fibromyalgia and Polymyalgia
- Chronic wrist and hand pain
- Sport injuries
- Scar hypersensitivity
- Plantar Fascitis
- People unable to take analgesic drugs

Clinical Applications

WOUND HEALING

Laser therapy optimises fibroblast proliferation, increases microcirculation, tissue oxygenation and cellular nutrition.
Wounds treated with the K-Laser are proven to heal faster, with increased tensile strength and reduced scar formation, preventing wound dehiscence.

- Diabetic wounds
- Non-healing ulcers
- Post-surgical wounds
- Burns

Validators

Guy's and St Thomas'
NHS Foundation Trust NHS

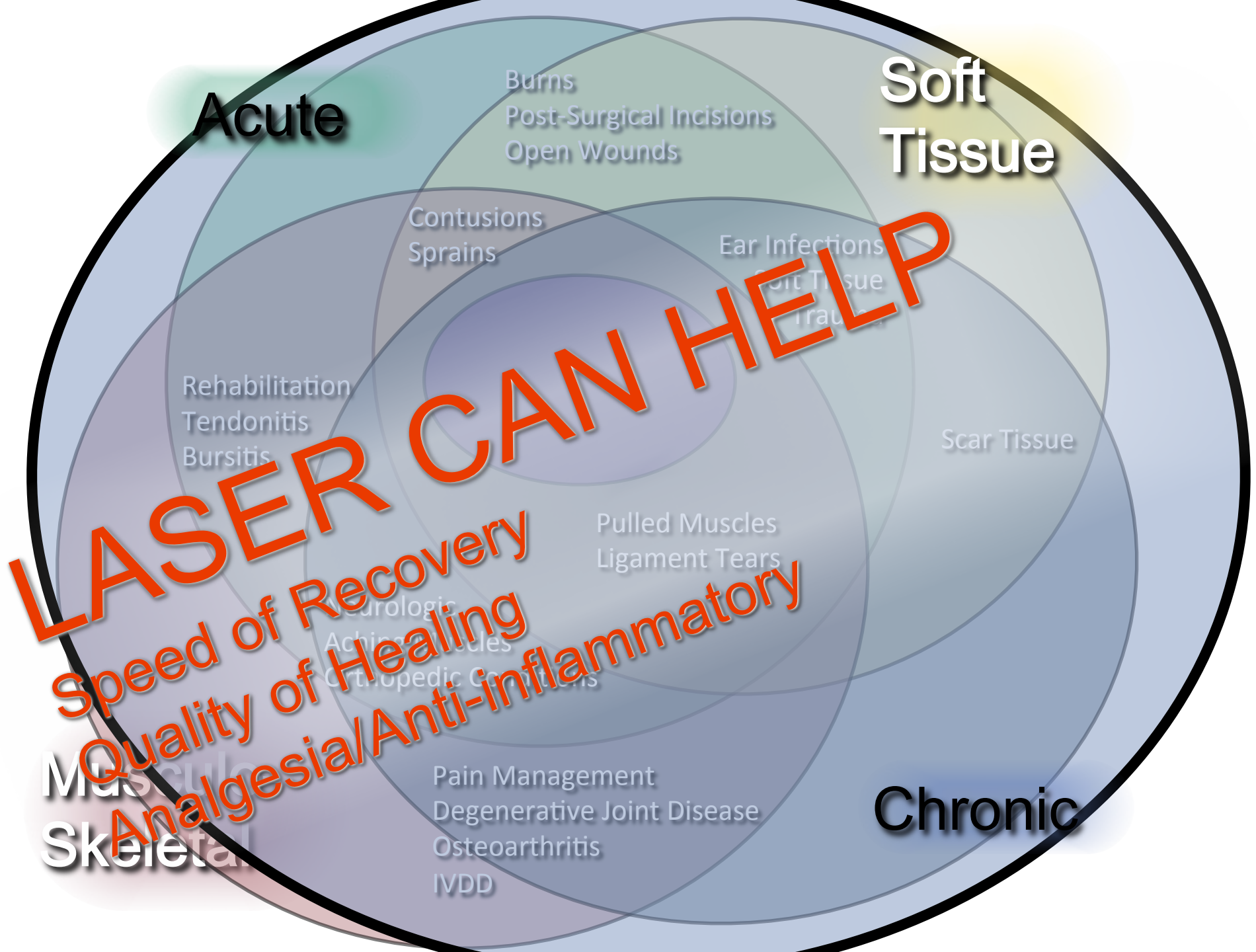
University of Glasgow
VIA VERITAS VITA

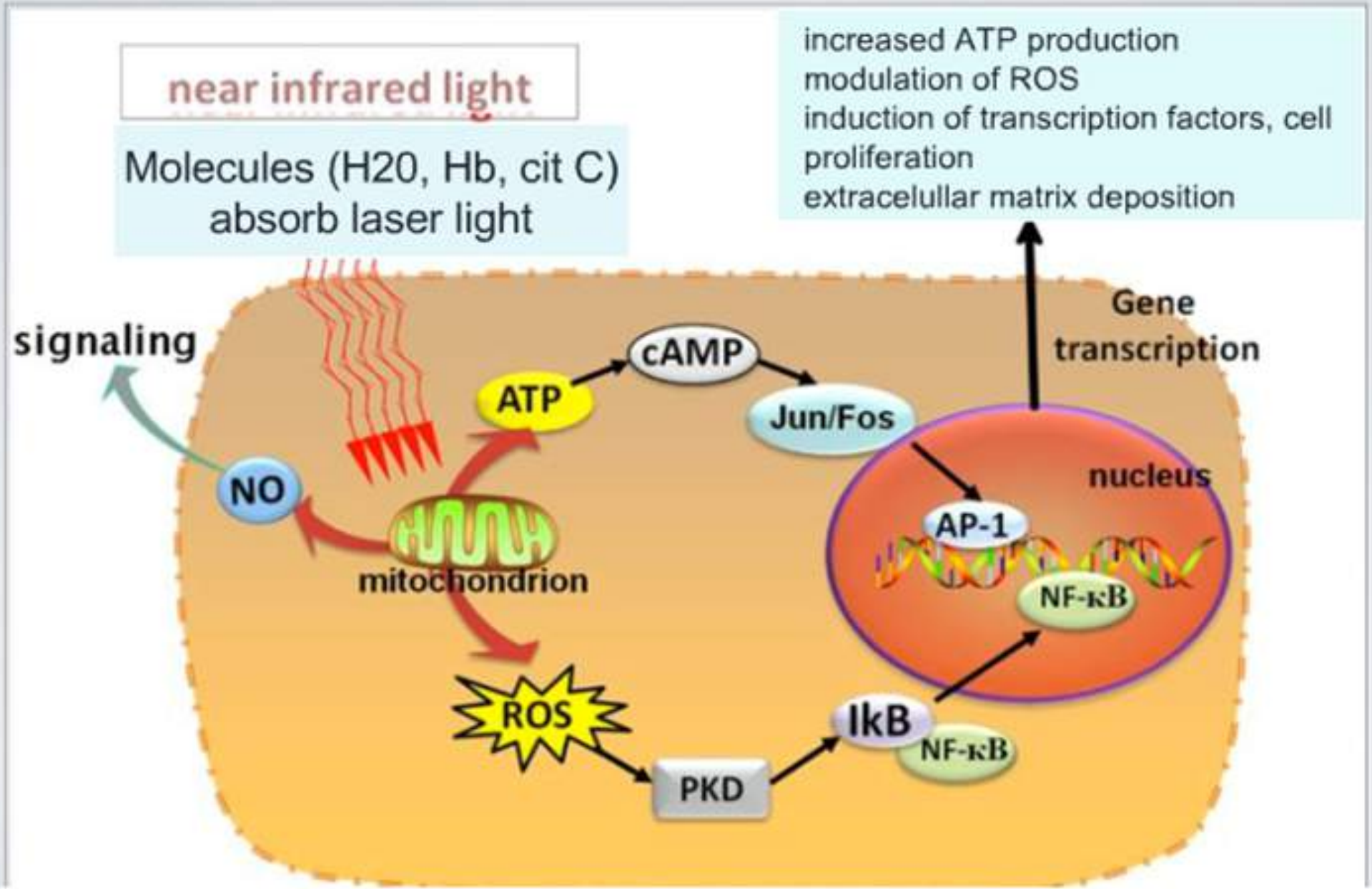
ICGEB International Centre for Genetic Engineering and Biotechnology
A Centre of excellence for research, training and technology transfer to industry in the field of biotechnology to promote sustainable global development
Developing Knowledge

UNIVERSITÀ DEGLI STUDI DI TRIESTE

Oregon State University

NHS
Kingston Hospital
NHS Foundation Trust


Acute
Soft Tissue
Chronic
Musculo Skeletal
Burns
Post-Surgical Incisions
Open Wounds
Contusions
Sprains
Ear Infections
Rehabilitation
Tendonitis
Bursitis
Scar Tissue
Pulled Muscles
Ligament Tears
Pain Management
Degenerative Joint Disease
Osteoarthritis
IVDD
LASER CAN HELP
Speed of Recovery
Quality of Healing
Analgesia/Anti-inflammatory

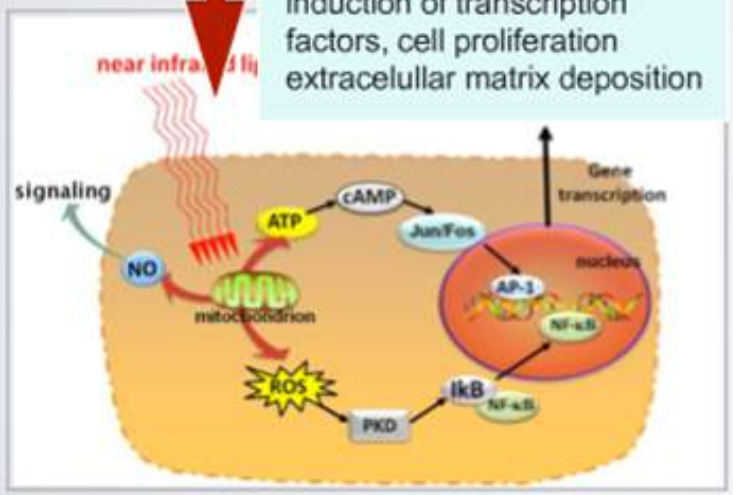


Huang YY, Sharma SK, Carroll J, Hamblin MR. Biphasic dose response in low level light therapy - an update. Dose Response. 2011;9:602–18

MEDICAL SCIENCE SUPPORTING EFFECTS OF LASER THERAPY: CELULAR MECHANISMS AND **BIOLOGICAL EFFECTS**

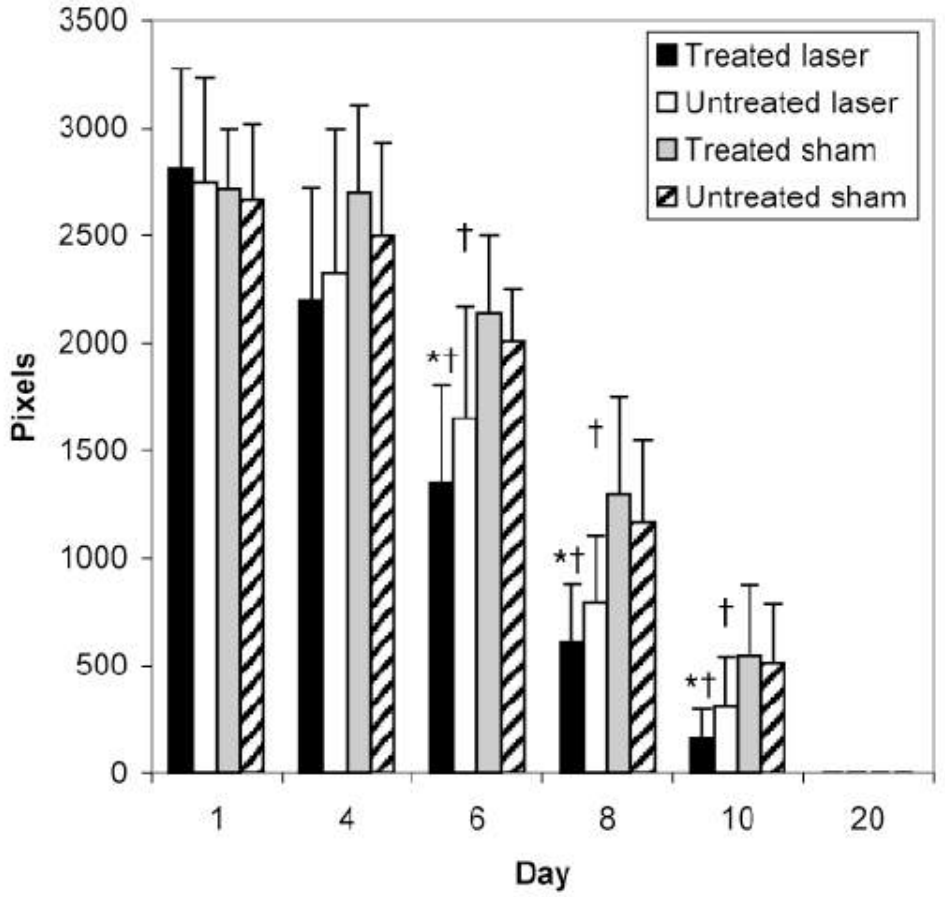
Molecules (H20, Hb, cit C) absorb laser light

increased ATP production
modulation of ROS
induction of transcription factors, cell proliferation
extracelullar matrix deposition



1. **Tissue healing:** common + specific phenomena
   - wound healing: post-sx wounds, second intention, ulcers
   - muscle, tendon and ligament repair
   - bone healing
   - nerve repair
2. **Anti-inflammatory**
   - Mechanisms
   - Different tissues: joints, mucosas, etc
3. **Anti-edema**
4. **Analgesia**
   - Effects on pain management
   - Analgesia in different conditions
5. **Potential risks**
6. **Integration with other therapies**

Low-Level Laser Therapy Facilitates Superficial Wound Healing in Humans: A Triple-Blind, Sham-Controlled



† Different from sham group ($P < 0.05$).
* Different from the untreated wound ($P < 0.05$).

Measurement:

- Wound area up to 20 days post wound

Results:

- The LLLT resulted in enhanced healing as measured by wound contraction.
- The untreated wounds in subjects treated with LLLT contracted more than the wounds in the sham group, so LLLT may produce an indirect healing effect on surrounding tissues.

Hopkins et a;. (2004) J Athletic Training

Wounds

Chronic Diabetic Ulcers

(Human)

Phototherapy Promotes Healing of Chronic Diabetic Leg Ulcers That Failed to Respond to Other Therapies

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[2]Department of Biotechnology, Federal University of the Amazon, Manaus, Brazil
[3]Division of Dermatology, Internal Medicine Department and School Health Center, Faculty of Medicine of Ribeirão Preto, University of São Paulo, Ribeirão Preto, Brazil
[4]School of Health Professions, Behavioral and Life Sciences, New York Institute of Technology, Old Westbury, New York

TABLE 2. Location of Ulcers in Both Groups of Patients

Group one ulcers	Group two ulcers
(1) Plantar surface of the left foot	(1) Plantar surface of the right hallux
(2) Medial area of the right lower leg	(2) Plantar surface of the left hallux
(3) Site of amputation, left metatarsals	(3) Medial area of the left lower leg
(4) Left lateral malleolus	(4) Anterior area of the left lower leg
(5) Anterior surface right lower leg	(5) Lateral area of the left lower leg
(6) Anterior surface upper right leg	(6) Lateral area of the left lower leg
(7) Left calcaneum	(7) Amputation site left lower leg
(8) Anterio-lateral area of the left lower leg	(8) Medial area of the right lower leg
(9) Anterio-lateral area of the right lower leg	(9) Anterior area of the right lower leg
(10) Lateral surface of the left lower leg	(10) Lateral area of the right lower leg
	(11) Posterior-lateral area of the right leg
	(12) Right Achilles tendon
	(13) Posterior area of the right lower leg

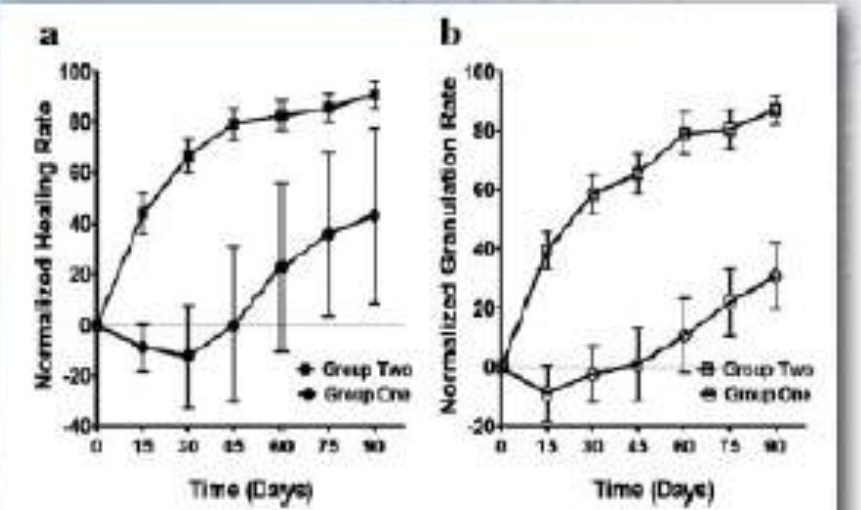

Fig. 2. Graphs showing normalized rates of healing (**a**) and tissue granulation (**b**) over time. In figure 2a, black square = healing rate of group two treated ulcers; black circle = healing rate of placebo treated ulcers. In figure 2b, white square = granulation rate of group two treated ulcers; white circle = granulation rate of placebo treated ulcers.

Dose: 3 J/cm²

n=23

Limb Blow Flow After Class IV Laser Therapy

- Modulating Circulation would promote healing by controlling post-injury ischemia, hypoxia, oedema and secondary tissue damage.
- No studies have quantified these responses to laser therapy

Journal of Athletic Training 2012

Journal of Athletic Training 2012;47(2):178–183
© by the National Athletic Trainers' Association, Inc
www.nata.org/jat

original research

Limb Blood Flow After Class 4 Laser Therapy

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*Department of Applied Physiology and Kinesiology, University of Florida, Gainesville; †Palm City, FL

Context: Laser therapy is purported to improve blood flow in soft tissues. Modulating circulation would promote healing by controlling postinjury ischemia, hypoxia, edema, and secondary tissue damage. However, no studies have quantified these responses to laser therapy.

Objective: To determine a therapeutic dose range for laser therapy for increasing blood flow to the forearm.

Design: Crossover study.

Setting: Controlled laboratory setting.

Patients or Other Participants: Ten healthy, college-aged men (age = 20.80 ± 2.16 years, height = 177.93 ± 3.38 cm, weight = 73.64 ± 9.10 kg) with no current history of injury to the upper extremity or cardiovascular conditions.

Intervention(s): A class 4 laser device was used to treat the biceps brachii muscle. Each grid point was treated for 3 to 4 seconds, for a total of 4 minutes. Each participant received 4 doses of laser therapy: sham, 1 W, 3 W, and 6 W.

Main Outcome Measure(s): The dependent variables were changes in blood flow, measured using venous occlusion plethysmography. We used a repeated-measures analysis of variance to analyze changes in blood flow for each dose at 2, 3, and 4 minutes and at 1, 2, 3, 4, and 5 minutes after treatment. The Huynh-Feldt test was conducted to examine differences over time.

Results: Compared with baseline, blood flow increased over time with the 3-W treatment ($F_{3,9}$ = 3.466, P < .011) at minute 4 of treatment (2.417 ± 0.342 versus 2.794 ± 0.351 mL/min per 100 mL tissue, P = .032), and at 1 minute (2.767 ± 0.358 mL/min per 100 mL tissue, P < .01) and 2 minutes (2.667 ± 0.369 mL/min per 100 mL tissue, P = .022) after treatment. The sham, 1-W, and 6-W treatment doses did not change blood flow from baseline at any time point.

Conclusions: Laser therapy at the 3-W (360–J) dose level was an effective treatment modality to increase blood flow in the soft tissues.

Key Words: therapeutic modalities, circulation, musculoskeletal injuries

Key Points

- Using a class 4 laser in a human clinical model, we found a protocol-response effect: a 3-W protocol at a 50% duty cycle applied to the biceps brachii muscle was the most effective for increasing blood flow to the distal forearm.
- Laser therapy is an effective, noninvasive treatment modality to improve blood flow and perhaps tissue healing in the clinical setting.

The use of laser as a clinical modality has increased greatly over the past decade. Positive effects of laser therapy for the treatment of acute and chronic musculoskeletal disorders include pain control[1,2] and improved tissue repair.[3,4] However, the underlying mechanisms and clinical effectiveness of laser therapy remain poorly understood.

Lasers are classified by power level and their ability to produce eye injury. These power and beam characteristic ratings are established by the American National Standards Institute and the International Electrotechnical Commission. Most therapeutic lasers available for use in clinical practice are classified as 3B or 4. Class 3B lasers emit power of 5 to 500 mW, whereas class 4 lasers emit power of more than 500 mW. A few therapeutic laser manufacturers offer divergent-beam power outputs greater than 10000 mW. Class 3B level emitting lasers are known as low-level, low-intensity, and cold lasers because they generate no significant thermal effect in the superficial tissue during irradiation. Class 4 lasers are known as high-power and hot lasers because they can produce rapid increases in superficial tissue temperatures when maximum permissible exposure limits are exceeded. Recent trends in laser therapy show a preference for class 4 lasers in patient care settings.[5] Class 4 lasers can emit greater photonic energy in a shorter period of time than class 3B lasers without producing an appreciable rise in tissue temperature under normal treatment protocols.[5] This higher power becomes important when treating injuries to deeper tissues such as ligaments, muscles, tendons, and cartilage.

Authors of most published clinical studies on laser therapy to treat musculoskeletal injuries have used class 3B low-power lasers. Several published reports[6,7] have questioned the ability of low-power lasers to effectively transmit energy beyond the skin into deep musculoskeletal tissues. Excessive beam scattering and attenuation within the skin limit the potential biostimulative effects of laser in the deeper target tissues because of several factors related to dosimetry, such as subthreshold optical power, insufficient treatment durations, and varied treatment frequencies.[8,9] Therefore, it is relevant and timely to study the dosimetric responses of specific infrared wavelengths of high-power class 4 lasers and their ability to modulate the physiologic effects that are conducive to healing.

Positive therapeutic effects of laser have been attributed to increased blood flow in soft tissues and, coincidentally, the

Limb Blow Flow After Class IV Laser Therapy

- Double-blinded, Crossover study
- 10 Healthy, college men
- No history of injury or cardiovascular conditions
- K-Laser used to treat biceps brachii muscle in grid pattern
- Placebo, 1W, 3W and 6W power dosages
- Plethysmography measures blood flow changes

- “Class 4 Lasers can emit greater photonic energy in a shorter time than Class 3B laser within producing an appreciable rise in tissue temperature. This higher power becomes important when treating injuries to deeper tissues such as ligaments, muscles, tendons and cartilage.”

Results

- 3W power pulsing mode 50%
- Significantly enhanced blood flow at 4 minutes during treatment vs Baseline
- ……and maintained improved blood flow 2 minutes post treatment

- “Improved circulation is considered one of the laser therapy’s greatest contributions to soft tissue healing after injury.”

“Our results show a dose-dependent effect of Class 4 laser therapy in a human clinical model….effective, non-invasive treatment modality to improve blow flow and promote tissue healing.”

Diabetes Care 2015

- Guy's & St Thomas Hospital
- Tertiary Diabetic Ulcer Unit
- Recruitment – non-healing diabetic ulcers (>3 yrs)
- Standard Podiatry and Medical therapy versus Additional K-Laser Therapy
- 80% healed within 12 weeks on K-Laser (av. 4.6 weeks)
- 0% healed within 12 weeks non-K-Laser placebo group

CrossMark

A Pilot Study to Evaluate the Efficacy of Class IV Lasers on Non-Healing Neuroischemic Diabetic Foot Ulcers in Patients With Type 2 Diabetes

Giuseppe Maltese,[1] Janaka Karalliedde,[1] Helen Rapley,[2] Tim Amor,[2] Alpa Lakhani,[2] and Luigi Gnudi[1]

Diabetes Care 2015;38:e1–e2 | DOI: 10.2337/dc15-0774

Diabetic foot ulcers (DFUs) represent a disabling complication of diabetes that has a devastating impact on the quality of life and predict lower-limb amputation and premature mortality (1). Despite best practice, 30–40% of DFUs do not heal within 12–20 weeks (2). Novel therapeutic agents have been tested in clinical trials and it has been estimated that ~30–50% of patients with neuropathic DFUs receiving these new treatments have healed by 12–20 weeks (3). Laser therapy, delivered with devices emitting one or two wavelengths, has been reported as an adjunctive procedure that promotes the healing of chronic diabetic wounds by increasing the blood flow and the release of growth factors and by reducing the inflammation (4).

In this pilot study, we have been the first to investigate the efficacy of an advanced class IV laser (emitting four wavelengths) on Wagner stage 1 and 2 neuroischemic DFUs of five patients with type 2 diabetes who were nonresponsive to conventional treatment for at least 12 weeks. Laser treatment was delivered once a week prior to standard care and dressing. As a control we selected patients with similar DFUs and clinical characteristics treated within our department with standard care. In the laser-treated group, age was 58.2 ± 3.6 years (mean ± SEM, range 47–66) and mean duration of diabetes was 20.4 ± 2.1 years. At the time of enrollment, glycosylated hemoglobin (HbA_{1c}) was 9.0 ± 0.8% (74.6 ± 8.4 mmol/mol). All laser-treated patients had preserved renal function (estimated glomerular filtration rate [eGFR] 72 ± 8.3 mL/min) and moderate to severe peripheral artery disease, defined as 20–49% and 50–99% diameter reduction in at least one of the arterial segments from aorto-iliac to popliteal segments on an arterial duplex scan. The mean size of the ulcers was 2.4 ± 1.0 cm^2. The control group of six patients with type 2 diabetes received standard care and had similar ulcer duration and size; comparable glycemic control, age, diabetes duration, and eGFR; and similar degree of peripheral artery disease (Table 1). Standard care for DFUs, including antibiotic treatment, dressing, and off-loading, was similar in both groups. Within the 12-week follow-up, four of five laser-treated patients (80%) had a complete ulcer resolution (most ulcers healed after 4.6 weeks). In the control group, no ulcer healing occurred by week 12.

A limited number of small clinical trials and case studies evaluating the effects of laser devices with lower power and one or two wavelengths on DFUs have previously reported positive outcomes (4). However, because of the heterogeneity in the methodology, findings from these studies have not been consistent. The laser used in this pilot study is the first example of a high-powered device with four wavelengths concomitantly acting on multiple metabolic processes that accelerate the wound healing: stimulation of cytochrome-C oxidase, an increase in angiogenesis, and improvement in blood perfusion (5).

Taking into consideration the limitations of this proof-of-concept study, our findings indicate that laser therapy delivered by a class IV laser can significantly impact the healing process of neuroischemic DFUs refractory to standard treatment. Randomized controlled clinical trials with this new laser device in larger populations are required to confirm our results.

Acknowledgments. The authors thank all patients who participated in this study, K-LaserUSA and VBS Direct Ltd. for providing the laser equipment, and Antonella Chierchia for her technical contribution to the study.

K-LaserUSA had no role in the design, data analysis, or preparation of the manuscript.

Duality of Interest. No potential conflicts of interest relevant to this article were reported.

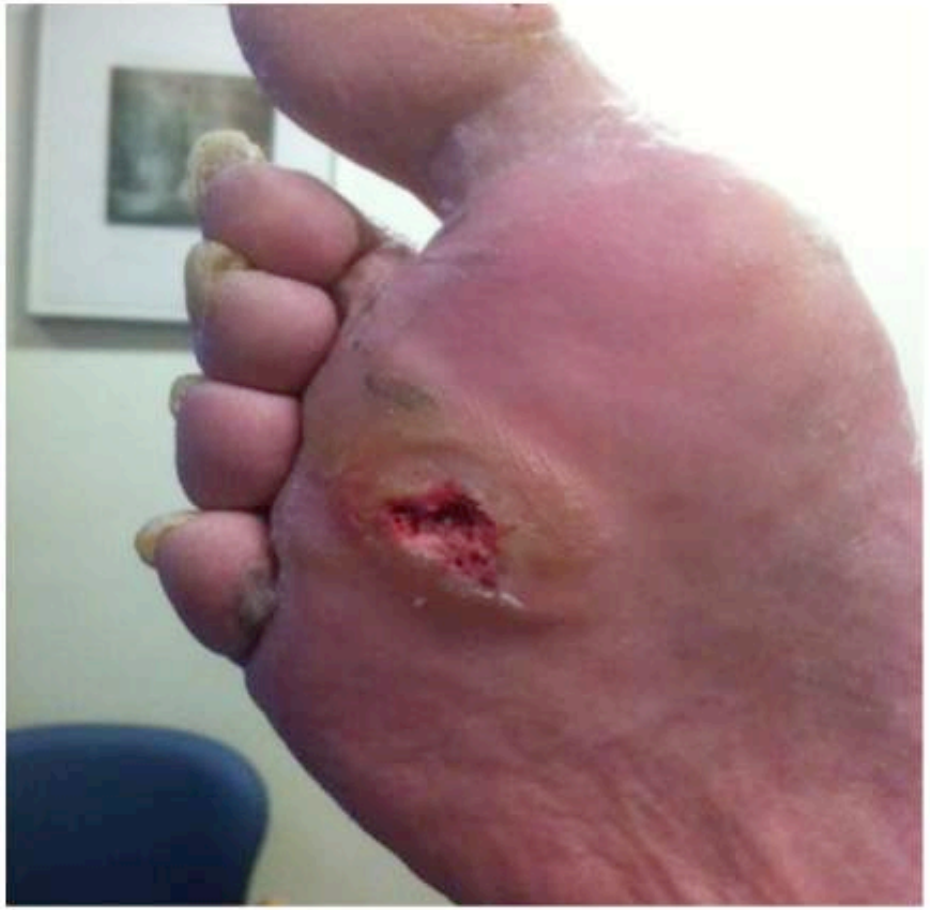
Author Contributions. G.M. managed the patients, researched the data, and wrote the manuscript. J.K. and L.G. reviewed the manuscript and contributed to the discussion. H.R., T.A., and A.L. delivered foot care and administered laser therapy. G.M. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

[1]Cardiovascular Division, Faculty of Life Sciences & Medicine, King's College London, London, U.K.
[2]Diabetes and Endocrinology Service, Guy's and St Thomas' Hospital NHS Foundation Trust, London, U.K.
Corresponding author: Giuseppe Maltese, giuseppe.maltese@kcl.ac.uk.

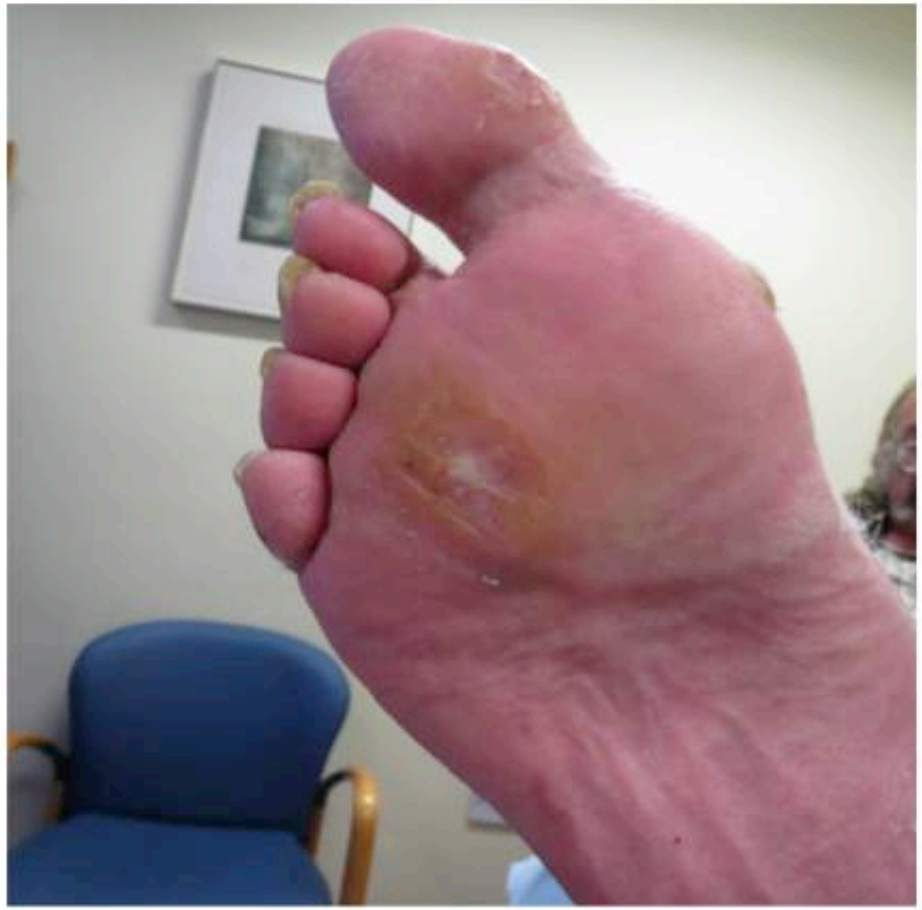
Received 13 April 2015 and accepted 24 April 2015.

St Thomas' Case Studies

15th August



29th August

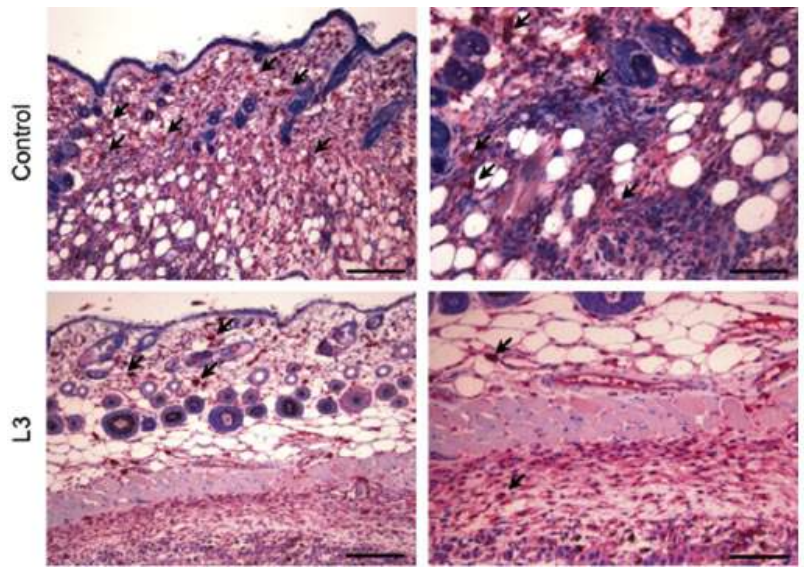


3 K-Laser sessions

Laser Therapy Inhibits Tumor Growth in Mice by Promoting Immune Surveillance and Vessel Normalization

Ottaviani Giulia [a,b], Martinelli Valentina [b], Rupel Katia [a,b], Caronni Nicoletta [d], Naseem Asma [d], Zandonà Lorenzo [c], Perinetti Giuseppe [a], Gobbo Margherita [a], Di Lenarda Roberto [a], Bussani Rossana [c], Benvenuti Federica [d], Giacca Mauro [c,e], Biasotto Matteo [a], Zacchigna Serena [b,c,*]

Laser therapy, recently renamed as photobiomodulation, stands as a promising supportive treatment for oral mucositis induced by oncological therapies. However, its mechanisms of action and, more importantly, its safety in cancer patients, are still unclear. Here we explored the anti-cancer effect of 3 laser protocols, set at the most commonly used wavelengths, in B16F10 melanoma and oral carcinogenesis mouse models. While laser light increased cell metabolism in cultured cells, the in vivo outcome was reduced tumor progression. This striking, unexpected result, was paralleled by the recruitment of immune cells, in particular T lymphocytes and dendritic cells, which secreted type I interferons. Laser light also reduced the number of highly angiogenic macrophages within the tumor mass and promoted vessel normalization, an emerging strategy to control tumor progression. Collectively, these results set photobiomodulation as a safety procedure in oncological patients and open the way to its innovative use for cancer therapy.



Class IV laser therapy as treatment for chemotherapy-induced oral mucositis in onco-haematological paediatric patients: a prospective study

Results. All patients demonstrated improvement in pain sensation, and all mucositis was fully resolved at the 11-day follow-up visit, with no apparent side effects. Laser therapy was well toler-

Multicenter randomized, double-blind controlled trial to evaluate the efficacy of laser therapy for the treatment of severe oral mucositis induced by chemotherapy in children: laMPO RCT

Variable			
Swallowing	60	20	**0.02**
Lips	47	27	**0.02**
Saliva	27	0	NS
Tongue	40	20	**0.03**
Mucosa	93	0	**0.001**
Oral hygiene	40	13	NS

ided
side
ects

of therapy – biostimulation, antiinflammation, antimicrobic, and antalgic – strongly encourage to consider HPLT part of everyday practise in the management of oncological paediatric patients affected by OM.

International Jo of Paediatric Dentistry 2015

Wounds

Post Inguinal-Hernia Surgery

(Human)

Photomedicine and Laser Surgery
Volume 28, Number 3, 2010
© Mary Ann Liebert, Inc.
Pp. 417–422
DOI: 10.1089/pho.2009.2548

Effects of Low-Level Laser Therapy on Pain and Scar Formation After Inguinal Herniation Surgery: A Randomized Controlled Single-Blind Study

Rodrigo Leal de Paiva Carvalho, M.S.,[1] Paulo Sérgio Alcântara, M.S.,[2] Fábio Kamamoto, M.S.,[2] Marcela Dalla Costa Cassiani, M.S.,[1] and Raquel Aparecida Casarotto, Ph.D.[1]

72% smaller scars

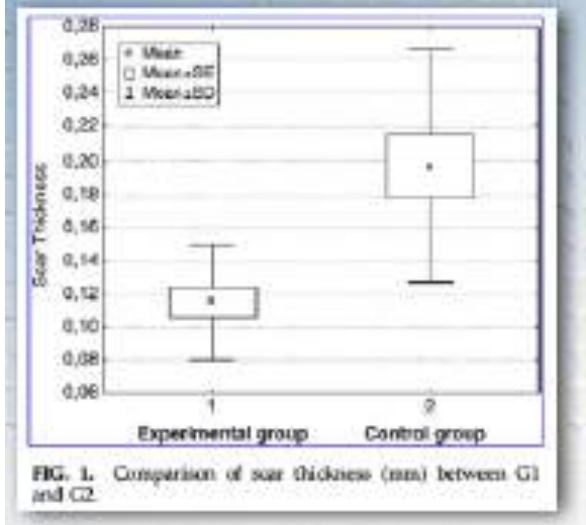


FIG. 1. Comparison of scar thickness (mm) between G1 and G2.

1266% Lower Score

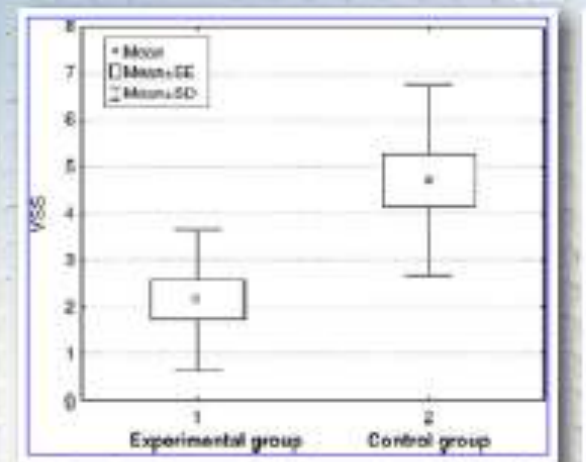


FIG. 2. Comparison of total VSS scores between G1 and G2.

VSS = Vancouver Scar Scale - measures vascularity, height/thickness, pliability, and pigmentation

82% Better Malleability

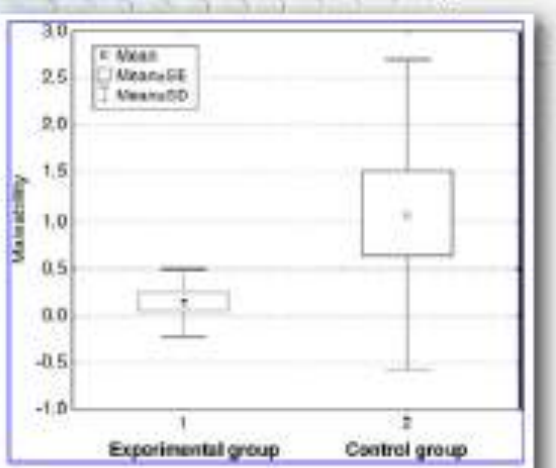


FIG. 3. Comparison of pliability scores between G1 and G2.

Dose: 13 J/cm²

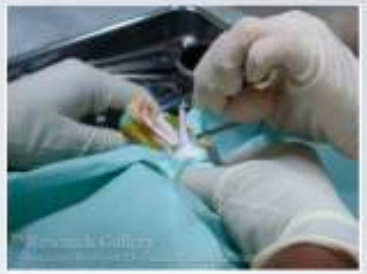
n=28

HEALING AND REPAIR OF TENDONS AND LIGAMENTS

INCREASE IN COLLAGEN PRODUCTION AND TYPE 1 COLLAGEN %

Reddy GK, Stehno-Bittel L, Enwemeka CS. Laser photostimulation of collagen production in healing rabbit Achilles tendons. Lasers Surg Med 1998;22:281–7.

increase in collagen production in the tenotomized rabbit Achilles tendon



BETTER ALIGNEMENT OF FIBERS

Oliveira FS, Pinfildi CE, Parizoto NA, et a l Effect of low level laser therapy (830 nm) with different therapy regimes on the process of tissue repair in partial lesion calcaneous tendon. Lasers Surg Med. 2009 Apr;41(4):271-6.

no significant difference between standard and 5 days application group

TABLE 1. Descriptive Measurement of Optical Delay (nm) Corresponding to Alignment of Collagen Fibers

Group	Average (nm)	SD
Group I	63.09	5.44
Group II	33.19	3.21
Group III	42.38	5.98
Group IV	62.18	9.27
Group V	46.22	2.59

Group I (standard); Group II (control); Group III (3 days); Group IV (5 days); Group V (7 days application).

INCREASE IN TENSILE STRENGHT

Fung DT, Ng GY, Leung MC, Tay DK. Therapeutic low energy laser improves the mechanical strength of repairing medial collateral ligament. Lasers Surg Med 2002;31:91–6.

660 nm, 31.6 J/cm2 and 63.2 J/cm2, transected medial collateral ligaments in rats

TENDINITIS, SPRAINS, POSTOPS OF TENDON SUTURES

If LT is used in combination with US it is advisable to use LT first and then US

The amount of type I collagen found in groups 2 (US), 3 (LLLT), and 5 (LLLT+US) was significantly higher than that in the control group (P□0.01), but no significant differences were found between treatment groups. The highest % of type I collagen was scored in the Laser+US group (830nm, 40 mw, 1.4 W/cm2, daily x 5 days, starting 1min after injury)

TABLE 1. Measurements (Mean ± Standard Deviation) of Optical Retardation and Percentage of Types I and III Collagen in the Different Study Groups

Groups	Optical retardation (nm)	Type I collagen (%)	Type III collagen (%)
Group1 (control)	33.5 (±2.7)	4.4 (±3.3)	60.5 (±22)
Group 2 (US)	42.3 (±7.1)	12.51 (±4.4)	51.5 (±11.63)
Group 3 (LLLT)	44.1 (±12.3)	12.3 (±5.5)	47 (±18.9)
Group 4 (US + LLLT)	40.4 (±6.4)	12.7 (±7.6)	48.55 (±16.6)
Group 5 (LLLT + US)	42.7 (±8.3)	15.2 (±5.8)	46.7 (±9.9)

US, ultrasound; LLLT, low-level laser therapy.

Wood VT et al. Collagen Changes and Realignment Induced by Low-Level Laser Therapy and Low-Intensity Ultrasound in the Calcaneal Tendon. Lasers in Surgery and Medicine 42:559–565 (2010)

LASER THERAPY VS. ULTRASOUND

Physiological Effect	Laser	Ultrasound
Increased Metabolism	Yes	Yes
Vasodilatation	Yes	Yes
Increased Pain Threshold	Yes	Yes
Increased Enzymatic Activity	Yes	Limited
Increased Membrane Permeability	Yes	Yes
Increased Ca++	Yes	No
Increased Mast Cell Degranulation	Yes	No
Angiogenesis	Yes	Yes
Increased Lymphocytes	Yes	No
Increased Collagen Synthesis	Yes	No
Nerve Regeneration	Yes	No
Osseointegration	Yes	No
Increased Fibroblasts	Yes	Yes
Improved Motor Nerve Conduction	Yes	No
Immediate post injury use	Yes	No
Cavitation danger	No	Yes
Transmission gel required	No	Yes

- OK over metal
- OK over broken skin
- OK over acute
- Easy over irregular parts
- No gel needed
- *BIOSTIMULATION!*

EFFECT OF NEAR INFRARED LASER LIGHT on MUSCLE FATIGUE

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Dept. of Health & Human Performance, Department of Physics and Astronomy
College of Charleston

COLLEGE of CHARLESTON

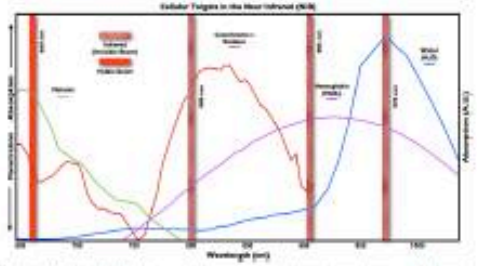
COLLEGE of CHARLESTON
SCHOOL OF EDUCATION, HEALTH, AND HUMAN PERFORMANCE

ABSTRACT

Laser therapy has been used for many years to assist in wound healing, attenuate inflammation, and reduce pain, all with the goal of improving performance. Recently, research has shown that low intensity near infrared light improves aerobic metabolism via cytochrome c oxidase stimulation. PURPOSE: This study aims to look at the impact of low intensity near infrared light on muscle fatigue. In addition to 800 nm light that is known to stimulate metabolism, our study includes 905 nm light that may work by impacting oxygen – hemoglobin binding. METHODS: Young adults (N=9) were randomly exposed (The Flexor Pollicis Longus, Flexor Digitorum Superficialis and Flexor Digitorum Profundus muscles were targeted) to either 800-nm laser light (K-LaserUSA, Franklin, TN), a combination of 800 and 905-nm light or a placebo while completing 50 maximal contractions on a hand grip dynamometer (Model DHD-1, Saehan Medical). The cadence for contraction and relaxation was set using a multimedia platform and the force of each contraction was recorded and used to generate a force/time curve. RESULTS: Both treatment and control groups exhibited the expected decrease in force production, however the treatment groups showed less force decrement than did the placebo group (p=0.0121 for 800 nm and p=0.0101 for the combination). CONCLUSIONS: These data indicate that treatment with an 800-nm laser light during exercise may attenuate muscular force decreases. 905-nm may improve the results. More work is needed to determine the mechanisms of action.

BACKGROUND

- Photobiomodulation – PBM is a non-thermal treatment, which can include visible or near infrared light, and at low doses is harmless to human tissue; interestingly however, when this light is administered consistently to a particular site on the body, it has been shown to be beneficial in its effects on muscle fatigue.
- Only a fraction of the light reaches the muscle layer because it is attenuated by absorption and scattering in the skin, adipose, and fascia layers. Therefore, both absorption and scattering reduce the intensity of the light radiation and weaken the level of light interacting with the muscle.

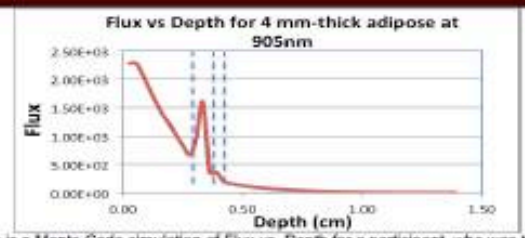


This graph from http://www.k-laserusa.com/mechanisms-of-action/ shows the absorption of 800 nm light by cytochrome c oxidase in the mitochondria and absorption of 905 nm light by hemoglobin.

METHODS

- Prior to any testing, and following a completed informed consent statement, height and body mass were measured.
- Subjects had their forearm measured from the middle of the medial humeral epicondyle to the ulnar styloid process to determine forearm length.
- Subjects then underwent a familiarization trial where they were shown how to use the hand grip dynamometer. They practiced several maximal contractions where they squeezed the dynamometer as hard as possible for 1.5 seconds.
- Subjects were also shown the low-level light and were allowed to see it demonstrated on a research assistant's forearm before having it demonstrated on their forearm.
- During the second and third visits the low level light or placebo treatment was applied to the forearm (at locations equal to 30% and 50% of the forearm length) while subjects performed 50 maximal hand grip trails. Each maximal contraction lasted 1.5 seconds and was separated by 2.5 seconds. A recording verbally instructed the subject to squeeze and release for all 50 repetitions.
- Prior to the first, and following the last, maximal hand grip reflectance scans were performed.
- Subjects were told to engage in their normal recreational activities but agreed not to engage in any new or additional resistance training or other strenuous activities 24 hours prior to each visit. Additionally, subjects were instructed to eat a meal within four hours, but not eat at least 60 minutes prior to, each trial. Furthermore, subjects will be informed that they may not consume any alcohol in the 24 hours before each testing session.

RESULTS

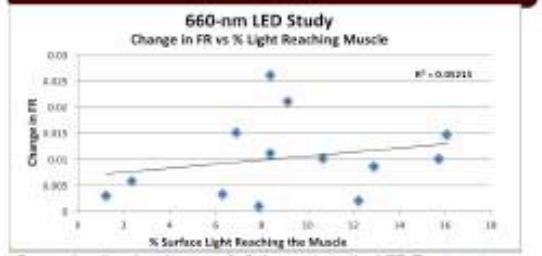


This is a Monte Carlo simulation of Flux vs. Depth for a participant, who was treated with 905nm light. The thickness of the adipose layer was estimated with skin fold measurements. This model includes Fascia. Each layer can be clearly seen by the varying flux levels at each tissue depth.

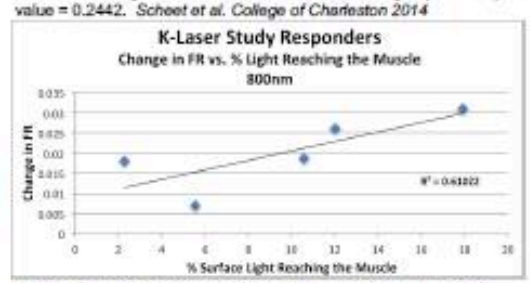
CONCLUSIONS

- These data show, for the first time, the impact of adipose tissue and fascia on the laser light that reaches the muscle.
- Also novel, is the finding that 800nm + 905 nm laser treatment during exercise can attenuate the decline in force production.
- Taken together, the prior findings of laser light impacts on metabolism (800 nm impacts Cytochorme C) and hemoglobin (905nm) and our finding of reduced fatigue rate, suggest laser light impacts skeletal muscle metabolism.
- More work is needed to determine the exact mechanisms of action and the most effective laser frequency/intensity.

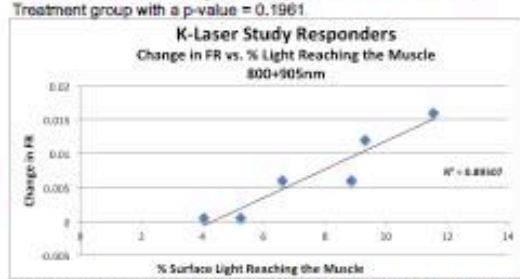
RESULTS



Comparing the placebo group's fatigue rate to the LED Treatment group (Microlight ML-830 LED) total of 18 J over 2-cm diameter area. There was no significant difference between the two groups with a p-value = 0.2442. *Scheet et al. College of Charleston 2014*



Comparing laser treatment to placebo (K-Laser Cube 4, K-LASER USA) 1.7W for 3 minutes 32 seconds for a total of 360 J over a forearm area of approximately 40 cm². There was no significant difference between the fatigue rate of placebo and the 800-nm Laser Treatment group with a p-value = 0.1961



Laser treatment with 800 + 905-nm. 1.7 W total power split between the two wavelengths for a total of 360 J over a forearm area of approximately 40 cm². Placebo group's fatigue rate was significantly higher than the 800 + 905-nm Laser group's with a p-value = 0.042.

This project was supported by grants from the National Center for Research Resources (5 P20 RR015401) and the National Institute of General Medical Sciences (8 P20 GM103499) from the National Institutes of Health.

CTS treated with a Diode Laser: a controlled treatment of the Transverse Carpal Ligament.

- 36 patients with mild to moderate degree of CTS
- Randomised into 2 groups (laser and sham treatment)
- 2 weeks (10 minutes sessions, 5 times per week)
- Assessment of symptomatic and functional changes
  - Nerve conduction; Grip strength and Visual Analogue Scale (VAS)

TABLE 5. RESULTS OF POST-TREATMENT AND TWO-WEEK FOLLOW-UP EVALUATION OF SYMPTOM AND FUNCTIONAL ASSESSMENT, HAND AND FINGER GRIP STRENGTH, AND NERVE CONDUCTION IN THE TWO STUDY GROUPS

	After 2 wk of treatment			*At 2-wk follow-up*		
	Laser group n = *20* *Mean ± SD*	*Placebo group* n = *20* *Mean ± SD*	p *Value*	*Laser group* n = *20* *Mean ± SD*	*Placebo group* n = *20* *Mean ± SD*	p *Value*
Symptom Severity Scale	21.67 ± 0.58	25.53 ± 0.62	0.138	19.35 ± 0.63	28.71 ± 0.85	0.006[a]
Functional Status Scale score	13.11 ± 0.63	17.04 ± 0.70	0.121	11.04 ± 0.43	19.60 ± 1.02	0.022[a]
Grip strength (kg)	19.71 ± 4.67	18.26 ± 4.55	0.415	21.19 ± 4.12	17.38 ± 3.56	0.014[a]
Lateral prehension (kg)	5.36 ± 1.56	4.62 ± 1.38	0.201	5.33 ± 1.33	4.35 ± 1.09	0.043[a]
Digital prehension (kg)	4.95 ± 1.30	4.70 ± 1.17	0.583	5.20 ± 0.83	4.43 ± 1.06	0.041[a]
SPL (ms)	3.75 ± 0.21	3.81 ± 0.11	0.243	3.67 ± 0.21	3.80 ± 0.11	0.065[a]
ML (ms)	4.03 ± 0.33	4.14 ± 0.18	0.364	3.87 ± 0.30	4.10 ± 0.21	0.053

CTS treated with a Diode Laser: a controlled treatment of the Transverse Carpal Ligament.

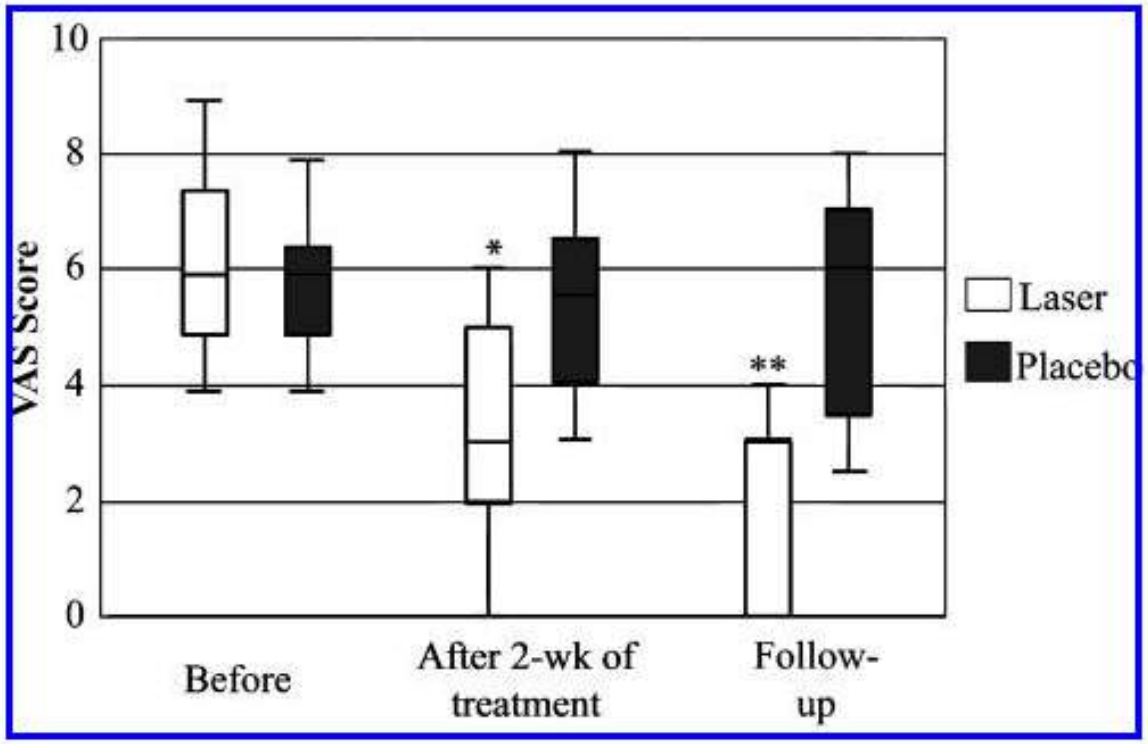


FIG. 1. Changes in VAS pre- and post-treatment and during follow-up in both of the groups (*p = 0.006 and **p = 0.001 on the Wilcoxon test; VAS , Visual Analog Scale).

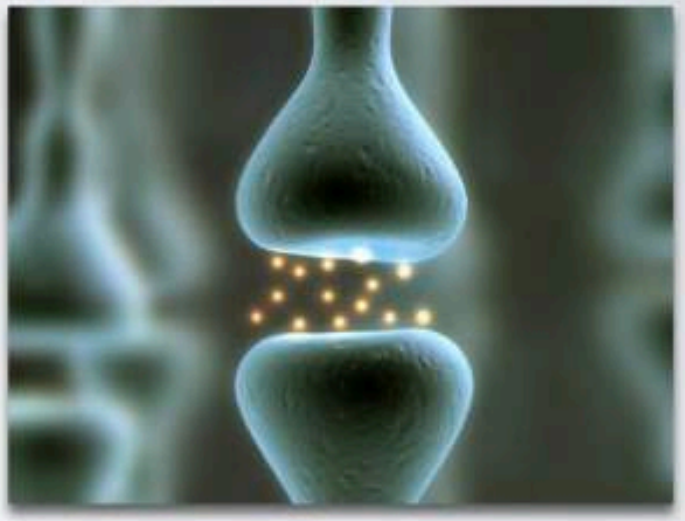
Conclusion:

- "LLT was effective in alleviating pain and symptoms, and improving functional ability in finger and hand strength in those with mild to moderate CTS with no side effects."

Chang W-D. et al. (2008

PROMISING RESULTS IN STROKE PATIENTS

- Improved **cerebral blood flow** after trans-cranial LT
- Decreased **apoptosis** after experimental CNS hypoxia
- Enhanced **neurogenesis** (and improved clinical outcomes) observed in subjects receiving transcranial LLLT following stroke. Pulsed radiation more effective than CW.



Lapchak PA, De Taboada L. Transcranial near infrared laser treatment (NILT) increases cortical adenosine-5'-triphosphate (ATP) content following embolic strokes in rabbits. Brain Res 2010;1306:100 – 105.

Uozumi Y et al. Targeted Increase in Cerebral Blood Flow by Transcranial Near-Infrared Laser Irradiation . Lasers in Surgery and Medicine 42:566–576 (2010)

Increase of Neuronal Sprouting and Migration Using 780nm LLLT

"Laser phototherapy irradiation accelerated neuron fibre sprouting and neuronal cell migration. Laser cultures contained much higher numbers of large sized neurons (P<0.01) which formed densely branched, interconnected networks of thick neuronal fibres."

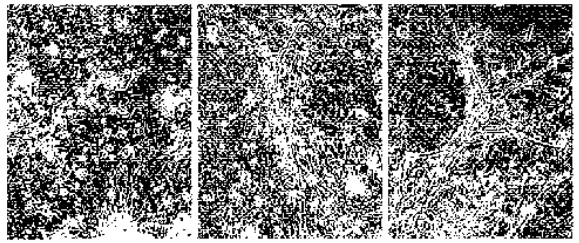


Fig. 3. Effect of laser irradiation on fiber outgrowth from cell-MC aggregates cultured in NVR-Gel. Note branching of thick nerve fibers in (**B**) (4 minutes) and (**C**) (7 minutes) after single irradiation of 50 mW in comparison with (**A**) control. Original magnification: 100×.

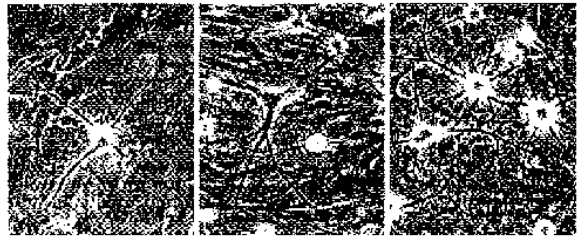


Fig. 5. Differences in nerve cell body size and fiber outgrowth between controls and laser irradiated cultures of rat embryonic brain. A number of large neurons, bearing thick branched neuronal fibers were observed in the irradiated cultures (**B**: 1 minute and **C**: 4 minutes irradiation) as compared to controls (**A**). Original magnification: 300×.

Lasers in Surgery and Medicine 41:277–281 (2009)

Increase of Neuronal Sprouting and Migration Using 780 nm Laser Phototherapy as Procedure for Cell Therapy

Shimon Rochkind, MD,[1]* Dalia El-Ani, PhD,[2] Zvi Nevo, PhD,[2] and Abraham Shahar, PhD[2]
[1]*Division of Peripheral Nerve Reconstruction, Tel Aviv Sourasky Medical Center, Tel Aviv University, Tel Aviv 64239, Israel*
[2]*NVR Labs, Ness Ziona 74031, Israel*

Background and Objectives: The present study focuses on the effect of 780 nm laser irradiation on the growth of embryonic rat brain cultures embedded in NVR-Gel (cross-linked hyaluronic acid with adhesive molecule laminin and several growth factors). Dissociated neuronal cells were first grown in suspension attached to cylindrical microcarriers (MCs). The formed floating cell-MC aggregates were subsequently transferred into stationary cultures in gel and then laser treated. The response of neuronal growth following laser irradiation was investigated.
Materials and Methods: Whole brains were dissected from 16 days Sprague–Dawley rat embryos. Cells were mechanically dissociated, using narrow pipettes, and seeded on positively charged cylindrical MCs. After 4–14 days in suspension, the formed floating cell-MC aggregates were seeded as stationary cultures in NVR-Gel. Single cell-MC aggregates were either irradiated with near-infrared 780 nm laser beam for 1, 4, or 7 minutes, or cultured without irradiation. Laser powers were 10, 30, 50, 110, 160, 200, and 250 mW.
Results: 780 nm laser irradiation accelerated fiber sprouting and neuronal cell migration from the aggregates. Furthermore, unlike control cultures, the irradiated cultures (mainly after 1 minute irradiation of 50 mW) were already established after a short time of cultivation. They contained a much higher number of large size neurons ($P<0.01$), which formed dense branched interconnected networks of thick neuronal fibers.
Conclusions: 780 nm laser phototherapy of embryonic rat brain cultures embedded in hyaluronic acid—laminin gel and attached to positively charged cylindrical MCs, stimulated migration and fiber sprouting of neuronal cells aggregates, developed large size neurons with dense branched interconnected network of neuronal fibers and, therefore, can be considered as potential procedure for cell therapy of neuronal injury or disease. Lasers Surg. Med. 41:277–281, 2009. © 2009 Wiley-Liss, Inc.

Key words: axonal sprouting; cross-linked hyaluronic acid with laminin gel; embryonic nerve cells; low power laser irradiation; microcarriers

INTRODUCTION

The therapeutic effect of low power laser irradiation (LPLI) was detected on peripheral and central nervous systems [1–6]. Previous studies, which evaluated the effects of LPLI on crushed injured peripheral nerves of rats, discovered protective immediate effects which increase the functional activity of the injured peripheral nerve [7]; maintenance of functional activity of the injured nerve over time [8]; decrease or prevention of scar tissue formation at the injured site [9]; prevention or decreased degeneration in corresponding motor neurons of the spinal cord [10]; increase in the rate of axon growth and myelinization, thus accelerating and improving the regeneration of the injured nerve. LPLI was found to increase migration and neurite sprouting of cultured embryonic nerve cells [11], as well as cultured adult brain microexplants [12], and to alter gene expression of olfactory ensheathing cells [13]. Our previous studies found that LPLI accelerated axonal growth into injured rat's spinal cord after an implantation of a composite implant, which was based on embryonic spinal cord nerve cells and cultured on biodegradable microcarriers (MCs) that were embedded in hyaluronic acid [6].

In this in vitro study we investigated the effect of 780 nm laser phototherapy on growth and development of embryonic brain neurons and their fibers in culture.

MATERIALS AND METHODS

Cell Culture

Sixteen-day-old rat embryos' (Sprague–Dawley) whole brains were dissected. After mechanical dissociation with narrow pipettes, 5×10^6 cells were suspended in medium attached to DE-53 positively charged cylindrical MCs in 60 mm bacteriological plastic dishes as previously described [14]. After 4–14 days in suspension, the formed floating cell-MC aggregates were collected and seeded in NVR-Gel (in 12 wells or 35 mm plastic dishes) as stationary cultures. Each single cell-MC aggregate was either treated with LPLI within 1 hour after seeding, or cultured without irradiation.

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DOI 10.1002/lsm.20757

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Pp. 577-589
DOI: 10.1089/pho.2008.2397

Original Article

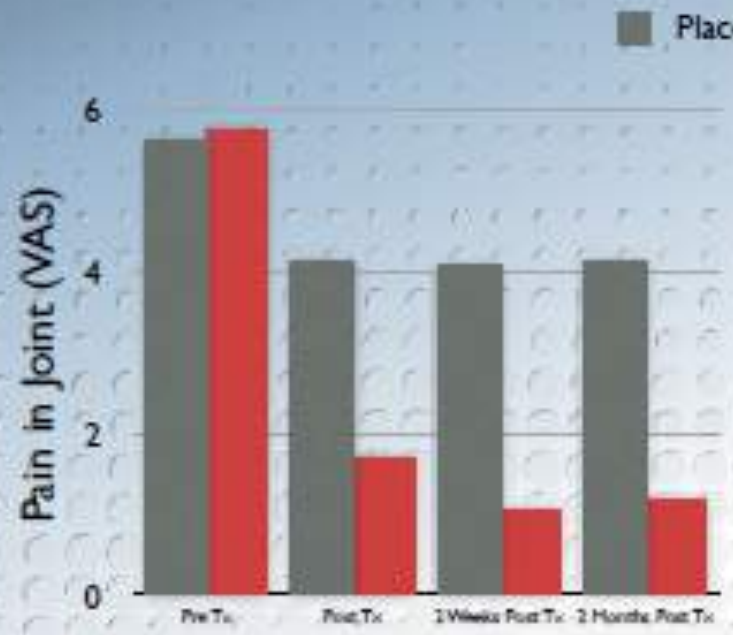
The Effect of Low-Level Laser in Knee Osteoarthritis: A Double-Blind, Randomized, Placebo-Controlled Trial

Béla Hegedüs, M.D.[1] Laszló Viharos, Ph.D.[2] Mihály Gervain, Ph.D.[3] and Márta Gálfi, Ph.D.[4]

Bone & Joint

Knee Osteoarthritis

(Human)



71% LESS Pain

10 % better
Range of Motion

after ***2 months***
and ***ONLY 1 TREATMENT***

Dose: 48 J/cm²

n=27

Contents lists available at ScienceDirect

Gynecologic Oncology

journal homepage: www.elsevier.com/locate/ygyno

The effect of photobiomodulation on chemotherapy-induced peripheral neuropathy: A randomized, sham-controlled clinical trial

Peter A. Argenta, MD [a,*], Karla V. Ballman, PhD [b], Melissa A. Geller, MD [a], Linda F. Carson, MD [a], Rahel Ghebre, MD [a], Sally A. Mullany, MD [a], Deanna G.K. Teoh, MD [a], Boris J.N. Winterhoff, MD [a], Colleen L. Rivard, MD [a], Britt K. Erickson, MD [a]

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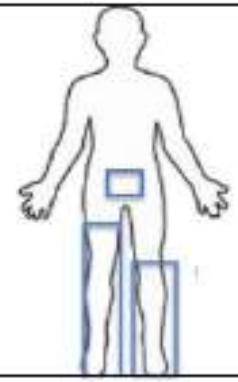
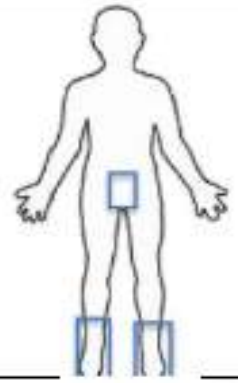
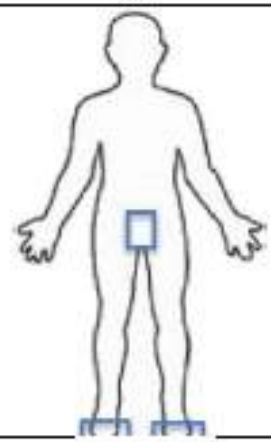
[b] Division of Biostatistics and Epidemiology, Department of Healthcare Policy and Research, Weill Cornell Medical School, New York, NY, United States

- Double-blinded, placebo controlled, cross over trial
- Chronic peripheral neuropathic pain study 70 females

- Class IV laser therapy using 4 wavelengths
- Average power 6.75 – 12W
- Total delivered on average 10,000 J over 1000cm^2
- Dosage 10J/cm^2

Treatment 1/18 360s @ 7.75W - Spine: L2-S2 180s @ 6.75W - Left Leg: popliteal fossa and fibula 240s @ 6.75W - Left Leg: popliteal fossa 300s @ 6.75W - Left Foot: malleoli 120s @ 6.75W - Right Leg: fibula 300s @ 6.75W - Right Leg: popliteal fossa 300s @ 6.75W - Right Foot: malleoli	
Treatments 2 – 8, data not shown	...
Treatment 9/18 360s @ 12.0W - Spine: L3-S2 240s @ 12.0W - Left Leg 480s @ 12.0W - Left Foot: malleoli 240s @ 12.0W - Right Leg 480s @ 12.0W - Right Foot: malleoli	
Treatments 10 – 17, data not shown	...
Treatment 18/18 360s @ 12.0W - Spine: L3-S2 720s @ 12.0W - Left Foot: malleoli 720s @ 12.0W - Right Foot: malleoli	

s - seconds; W – watts; L – lumbar; S – sacral

Contents lists available at ScienceDirect

Gynecologic Oncology

journal homepage: www.elsevier.com/locate/ygyno

The effect of photobiomodulation on chemotherapy-induced peripheral neuropathy: A randomized, sham-controlled clinical trial

Peter A. Argenta, MD [a,*], Karla V. Ballman, PhD [b], Melissa A. Geller, MD [a], Linda F. Carson, MD [a], Rahel Ghebre, MD [a], Sally A. Mullany, MD [a], Deanna G.K. Teoh, MD [a], Boris J.N. Winterhoff, MD [a], Colleen L. Rivard, MD [a], Britt K. Erickson, MD [a]

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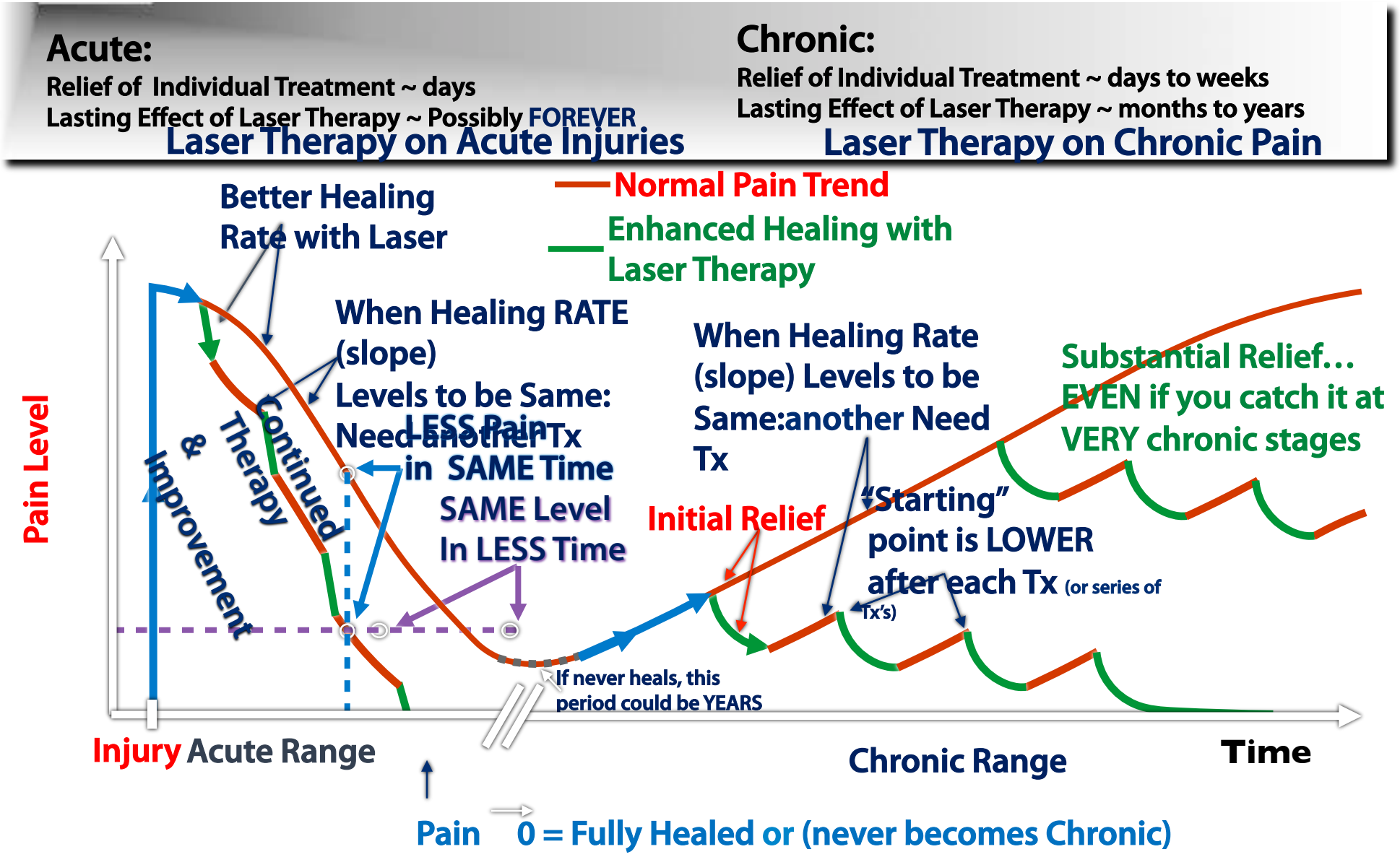
[b] Division of Biostatistics and Epidemiology, Department of Healthcare Policy and Research, Weill Cornell Medical School, New York, NY, United States

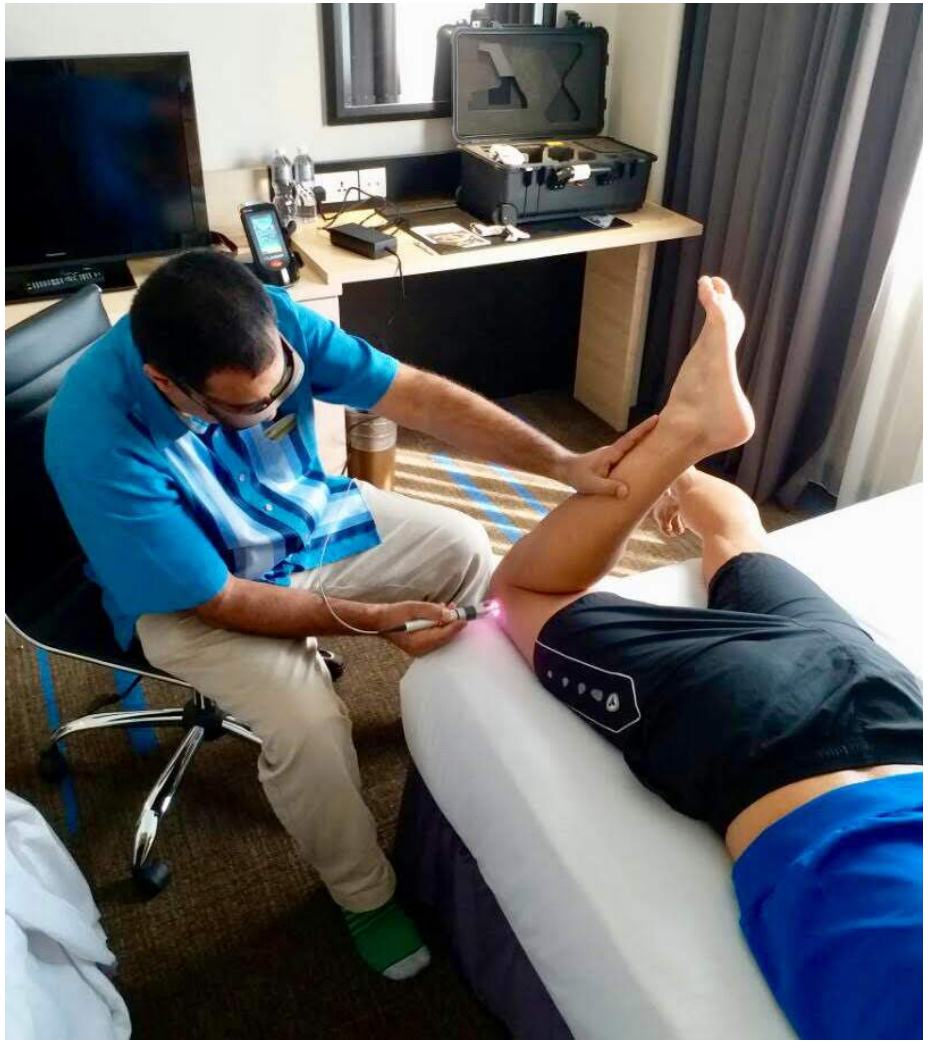
- "No observed complications amongst patients treated."
- "Our data indicate that PBM is an effective, low-toxicity treatment for chemotherapeutic induced peripheral neuropathies."
- "PBM may improve neuropathic symptoms through a number of plausible mechanisms including prevention of neuronal apoptosis and enhancement of neurite outgrowths."

How long do Laser Effects Last?



K-Laser Typical Protocol

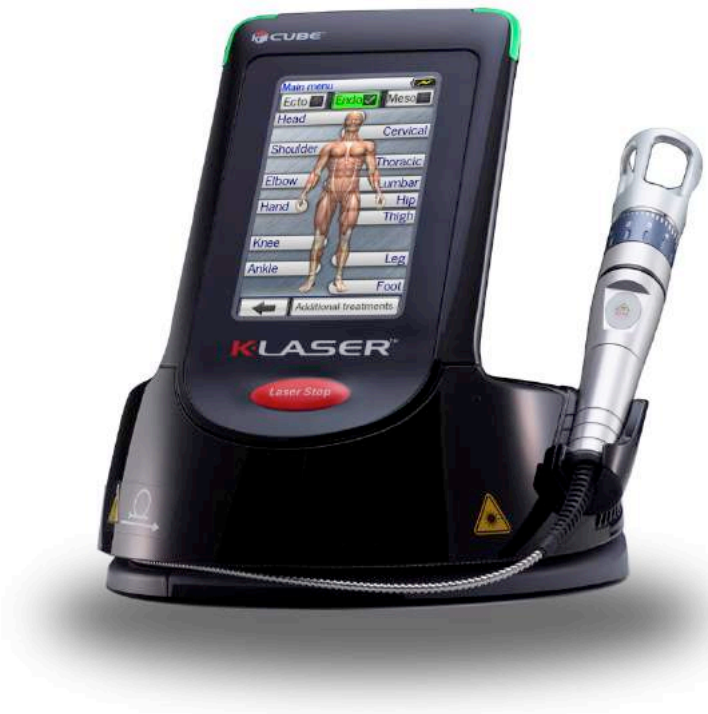
- Chronic Musculoskeletal
  - Initial 6 Treatments
  - 3, 2, 1 or 2,2, 2 over initial 3 weeks
- Acute Injuries
  - 2 - 6 Treatments (eod or daily)
  - Daily or at least 2-3 times per week
- Pre/Post Surgery Rehab
  - 2 – 6 Treatments (eod or daily)
  - Consultation day & Pre-operation
  - Anaesthesia recovery (skin only)
  - Discharge day & 2 – 6 more sessions
- Wounds
  - Can be given daily- high frequency
  - Contaminated wound = higher power
  - Clean wound settings on surgical table



K-Laser Overview and Financial Return

K-LASER®

- Up to 4 therapeutic wavelengths.
- Class VI power.
- CW, Pulse, Intense Super Pulse.
- Pre-set protocols tailored on Body size, Body part, Condition, Skin color, Level of pain, Chronicity of pain.
- Shorter treatment times: 3.5 minutes average protocol.
- Portability for out-of-clinic services.
- Used in independent international studies.
- Constant Research and Development.
- Linking to internet.
- Software: high stability, regularly updated.
- CE and FDA approved.
- Easy maintenance, no consumables.
- Lifetime warranty on the diodes
- Online Portal.
- On Demand.



Laser Finance Cost Per Day

- Hypothetical cost of the device: £16,000
- Cost per working day with a finance option: £7
- Minimum charge for a laser session: £20
- (common charges £30 to £60, NHS £42, Harley Street clinics £80-110)
- 1 session per day covers the daily cost of the device, following sessions are profit.

Equipment Cost (Excluding Vat)	£16,000.00

	2 Year Term	3 Year Term	4 Year Term	5 Year Term
Monthly Payment	£723.36	£501.12	£390.08	£323.36
Less tax at 40%	£289.34	£200.45	£156.03	£129.34
Net Cost	£434.02	£300.67	£234.05	£194.02
Weekly Cost	£100.16	£69.39	£54.01	£44.77
Daily Cost	£14.27	£9.89	£7.69	£6.38

Available on lease or lease purchase plans.

Payments fixed for term of agreement giving certainty of cash flow

Return on Investment

Weekly Opportuntitiy Evaluation				
Practice Name:				
Number of Medical Doctors	One and Half FTE Practice			
Client Compliance %:	10%	20%	25%	
Weighted Total (weekly):	£ 304.00	£ 608.00	£ 760.00	
Weighted Total (monthly)	£ 1,317.33	£ 2,634.67	£ 3,293.33	
Weighted Total (yearly):	£ 15,808.00	£ 31,616.00	£ 39,520.00	

Condtion	Cases	# TX's	Fee/TX	Total
Post Surgical Rehab	4	6	£ 20.00	£ 480.00
Chronic Conditions	8	12	£ 20.00	£ 1,920.00
Acute Conditions	8	4	£ 20.00	£ 640.00
Total	20		Weekly Total	£ 3,040.00
			Monthly Total:	£ 12,160.00
Based on theorectical 100% compliance			Yearly Total:	£ 158,080.00

Therapeutic Class IV Lasers

	£
Loan amount	20,000
Interest rate	8%
Monthly repayment	406
Total amount payable	24,332

Therapeutic Class IV Lasers

Prices charged

Service	£ ex VAT
Single musculoskeletal	31.67
Musculoskeletal six applications (@£26.44)	158.63
Oedema	31.67
Pain management	31.67
Post surgery	31.67
Soft tissue	31.67
Post dentistry	31.67

Therapeutic Class IV Lasers

Profitability formula

Costs of administration of laser	Revenue £/month	£/month
Finance repayments		406
Staff Compensation @ £12.50/hour, assume two cases per week (x per month)		
Building overheads and other fixed costs		£12/hour
Laser servicing £500 every 3 years		14
Total costs per month		
x cases @ £31.67	£31.67x	
Profit per month		

Therapeutic Class IV Lasers

Costs of administration of laser	Revenue £/month	£/month
Finance repayments		406
Staff Compensation @ £12.50/hour, assume two cases per week (9 per month)		27
Building overheads and other fixed costs		20
Laser servicing £500 every 3 years		14
Total costs per month		467
9 cases @ £31.67	285	
Profit per month		**(182)**

Therapeutic Class IV Lasers

Costs of administration of laser	Revenue £/month	£/month
Finance repayments		406
VN compensation @ £12.50/hour, assume four cases per week (17 per month)		54
Building overheads and other fixed costs		51
Laser servicing £500 every 3 years		14
Total costs per month		525
17 cases @ £31.67	538	
Profit per month		**13**

Therapeutic Class IV Lasers

Costs of administration of laser	Revenue £/month	£/month
Finance repayments		406
Staff Compensation @ £12.50/hour, assume one case per day (21 per month)		66
Building overheads and other fixed costs		63
Laser servicing £500 every 3 years		14
Total costs per month		559
21 cases @ £31.67	697	
Profit per month		**148**

Therapeutic Class IV Lasers

Costs of administration of laser	Revenue £/month	£/month
Finance repayments		406
Staff Compensation @ £12.50/hour, assume four cases per day (86 per month)		269
Building overheads and other fixed costs		258
Laser servicing £500 every 3 years		14
Total costs per month		947
86 cases @ £31.67	2724	
Profit per month		**1777**

Therapeutic Class IV Lasers

Rate of return

Example Medical Practice

$return - investment / investment$ x 100 over five years

$80520 - 24332 / 24332$ = 2.31 x 100 = **231%** ROR over five years

Therapeutic Class IV Lasers

Rate of return

Example 3 property. Typical ROR 6%

$return-investment/investment$ x 100 over five years

$32820-24332/24332$ = 0.35 x 100 = **35%** ROR over five years