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Contents

Laser photo-induced effects: a focus on the photothermal interaction.

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ABSTRACT

Laser therapies are based on the principle of light absorption by tissues and rely on three types of interactions: photochemical, photothermal and photomechanical interactions. In the first case, the photon energy is employed to trigger photochemical reactions, in the second the energy is converted into heat, while in the latter case mechanical effects are elicited. The prevalence of one or the other effect can be studied by considering the "chart of photo-induced effects" as detailed below. Generally speaking, laser interaction with tissue is governed by the following parameters: (i) laser wavelength, irradiance and light delivery mode for the laser source; (ii) the absorption and scattering properties (i. e. absorption and scattering coefficients) for the tissue. Irradiance, defined as the amount of light energy impinging on the tissue per unit of time and area, determines the intensity of the laser beam interacting with the target tissue.

After introducing a classification of the photo-induced effects, we will concentrate on the photothermal ones, analyzing their role in both therapeutic effects and safety issues.

INTRODUCTION

Chart of photo-induced effects

When laser light interacts with biological tissues, different effects can take place, depending on both the tissue's properties and the parameters of the light source [1-3]. These effects can be initially divided into two main categories: radiative processes, which involve the emission of energy in the form of light or other electromagnetic radiation, and non-radiative processes, where the absorbed energy is dissipated through mechanisms such as heat generation or molecular vibrations, without the emission of radiation. In this discussion, we will focus solely on non-radiative processes, as radiative effects are generally negligible in the context of photo-therapies and are mainly relevant for diagnostic applications only.

Non-radiative processes can be categorized using a diagram (Fig. 1) that associates them with two critical factors: the light irradiance (*E*) at the tissue surface and the duration of the laser exposure (τ_{laser}). The irradiance is generally measured in Watt / cm^2 and can either be calculated from the laser emission characteristics — factoring in potential changes due to reflections, beam expansion in air, or interaction with other tissues — or measured directly with a power meter, which generally returns a power value. Then, accurately determining *E* requires proper estimation of the beam's spot size at the air-tissue interface, which may involve various tools. These range from simple instruments like rulers or calipers to more advanced methods such as Knife-edge techniques. Another option involves using light-sensitive films, such as Gafchromic™ films, which can provide a resolution of up to 50 µm in the UV-visible range. However, newer versions of these films like the EBT3 model show reduced sensitivity to visible light, though they still perform well in certain UV ranges. A reasonably precise estimate of τ_{laser} by the operator is often sufficient to predict the primary effects, as outlined in Fig. 1. This estimation is valid when τ_{laser} corresponds directly to the treatment duration or is appropriately derived from the operational characteristics of the laser being used in the case of pulsed lasers.

Once both E and τ_{laser} are established, their product yields the energy fluence [J/m^2], which represents the energy per unit area delivered to the biological tissue. In Fig. 1, inclined lines are characterized by constant energy fluence values, aiding in the visualization of how the same energy fluence can be achieved under different combinations of *E* and τ_{laser}. Based on the increasing energy fluence values, the three main photo-induced effects are identified: photochemical, photothermal, and photomechanical. It can be noticed that photochemical interaction is predominant for lower irradiance values and higher interaction time; if these two parameters

increase, photothermal interactions become visible until they eventually account for the primary interaction mode. It is important to remember that more than one effect can be present at the same time; the chart in Fig. 1 can help in predicting if and which of them will be predominant in given irradiation conditions.

Photothermal effects

When a biological tissue is irradiated with a laser beam, the photons may be absorbed by various molecules within the tissue, known as chromophores. This absorption leads to an increase in the energy state of these molecules, which then dissipate energy as heat through molecular vibrational and rotational modes. The efficiency of this process is highly dependent on the tissue's specific optical properties, particularly its absorption coefficient, which varies with the wavelength of the incident light.

The photothermal effect is largely determined by the tissue's endogenous absorbers, including water, hemoglobin, and melanin. These chromophores absorb light at specific wavelengths, making the photothermal response wavelength-dependent. For instance, water strongly absorbs infrared radiation, while melanin and hemoglobin absorb light primarily in the visible and near-infrared regions. This wavelength-dependent absorption must be carefully considered when selecting lasers for therapeutic purposes, as it dictates both the depth of penetration and the nature of the thermal effect produced in the tissue.

For a more detailed discussion on the absorption properties of optical radiation by the most prevalent chromophores in biological tissues, we refer to the review by Martins et al. 2023 [5]. In that study, the absorption and effective absorption coefficients μ_a and μ_{eff} are precisely defined, which is the physical parameter that quantifies the overall light absorption. It is important to highlight that a specific molecule absorbs light differently depending on the wavelength. Therefore, a single absorption value cannot be applied across a broad range of wavelengths. Instead, for each specific λ, the corresponding absorption coefficient must be used. Failing to do so could result in significant errors in the analysis or application. This wavelength-dependent absorption is critical in applications like laser therapy, where precise energy deposition in the tissue is required for therapeutic efficacy and to avoid unintended damage. Understanding and applying the correct absorption coefficient for the relevant wavelength ensures that the interaction between light and tissue is accurately modeled, leading to more controlled and predictable outcomes.

For a more detailed discussion on the pathological effects of temperature increase in tissues, we refer to Douplik [1] and Thomsen [6]. For a quick overview of photothermal effects, Table 1 summarizes the main effects that can be induced depending on the temperature reached by the biological tissue. Some of these effects can be classified as reversible or irreversible, based on whether the tissue can return to its normal state once the temperature increase ceases. Reversible damage allows the cell or tissue to recover, while irreversible damage occurs rapidly, typically within seconds to minutes, and cannot be repaired through natural healing processes, which usually take days or weeks. Fig. 2 illustrates the conditions under which irreversible biological effects are achieved.

The temperature increase in biological tissue can be induced using an optical source that operates either in continuous or pulsed mode. In the first case, with continuous operation, energy is delivered steadily and continuously until the operator decides to stop the laser emission, resulting in gradual and uniform heating of the tissue. In contrast, pulsed optical sources emit laser radiation in short, repeated bursts. The pulse duration, repetition rate, and delivered energy are parameters that depend on the specific type of source used and may or may not be adjustable by the operator. The overall treatment duration, therefore, corresponds to a different number of pulses delivered. This method generally allows heat to be concentrated in localized areas, lim-

TISSUE TEMPERATURE	PHOTOTHERMAL EFFECTS
42°C – 45°C	Protein structural changes, hydrogen bond breaking, retraction
45°C – 50°C	Enzyme inactivation, changes in membrane permeabilization, oedema
50°C – 60°C	Coagulation, protein denaturation
~ 80°C	Collagen denaturation
80°C – 100°C	Dehydration
> 100 °C	Boiling, steaming
100°C – 300°C	Vaporisation, tissue ablation
> 300 °C	Carbonisation

Table I. Photothermal effects of laser-tissue interaction as function of the tissue temperature.

iting thermal diffusion to surrounding tissues and reducing the risk of collateral damage. In fact, if we consider pulsed lasers, the photothermal effects depend on the pulse duration (t_{pulse}) and the specific tissue thermal properties, which are represented by the so-called "thermal relaxation time" ($t_{thermal}$). This characterizes the time with which heat is dissipated in the tissue, starting from the volume where laser absorption takes place. Formally, $t_{thermal}$ is defined as a function of the laser penetration depth and the tissue thermal diffusion coefficient, and will be the object of a specific article. Here, we would just like to mention that the following two cases can be discussed: (i) $t_{pulse} << t_{thermal}$; (ii) $t_{pulse} >> t_{thermal}$. In case (i), heat is confined in the volume where laser absorption takes place, leading to a high and local temperature increase. Case (ii) represents the opposite occurrence, where heat is dissipated in the surrounding regions during the photothermal energy release, therefore heating a greater tissue volume but limiting the temperature increase. The choice of laser wavelengths and laser pulse duration determines the occurrence of one or the other case.

The heat generated during laser-tissue interaction can be exploited in therapy [7-10], both in the treatment of musculoskeletal pathologies and in regenerative medicine, according to the modality and timing of heat release. At the same time, photothermal effects are associated with laser-safety issues, for both the patient and the operator, in the case they are not the main desired interaction pathway when using laser light in the medical field [11]. When the energy delivered by the laser is too high, or the exposure time is too long, the resulting temperature rise can cause tissue damage, leading to burns or other injuries. To mitigate these risks, stringent safety protocols are required, encompassing both the technical parameters of laser systems and the training of personnel. Compliance with safety standards, such as those set by international guidelines, ensures that the therapeutic benefits of laser treatment are realized without compromising safety.

CONCLUSIONS

In conclusion, the interaction between laser light and biological tissue is a complex process governed by the wavelength-dependent absorption of light by endogenous chromophores. This interaction

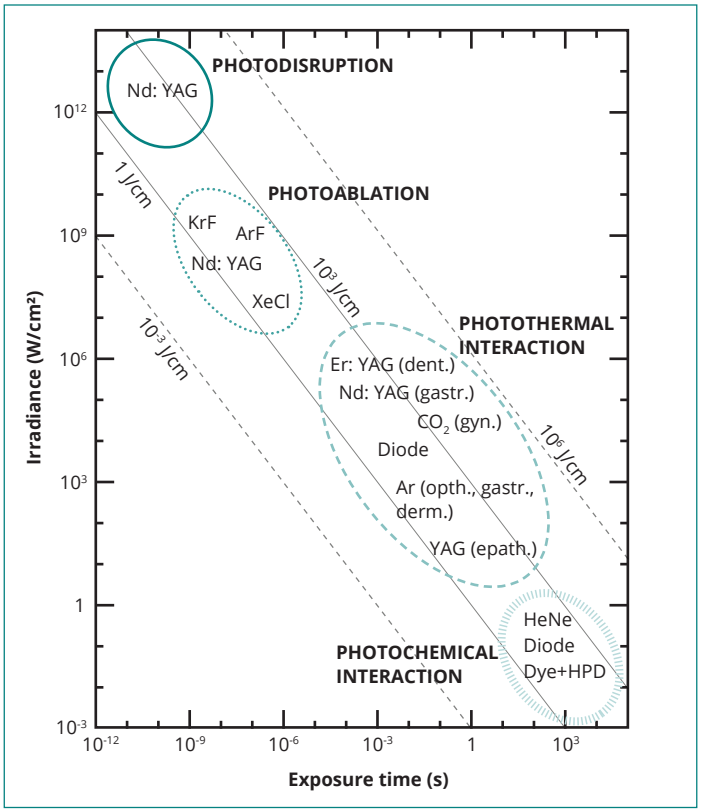

Figure 1
Map of photo-induced effects reported as function of the exposure time τ_{laser}, expressed in second (s) and light source irradiance E, in W/cm^2 [4].

forms the basis for photothermal effects, which are widely utilized in medical therapies. The proper understanding and management of these effects are crucial not only for achieving therapeutic efficacy but also for adhering to laser safety protocols, ensuring that laser treatments are both effective and safe for patients and operators alike.

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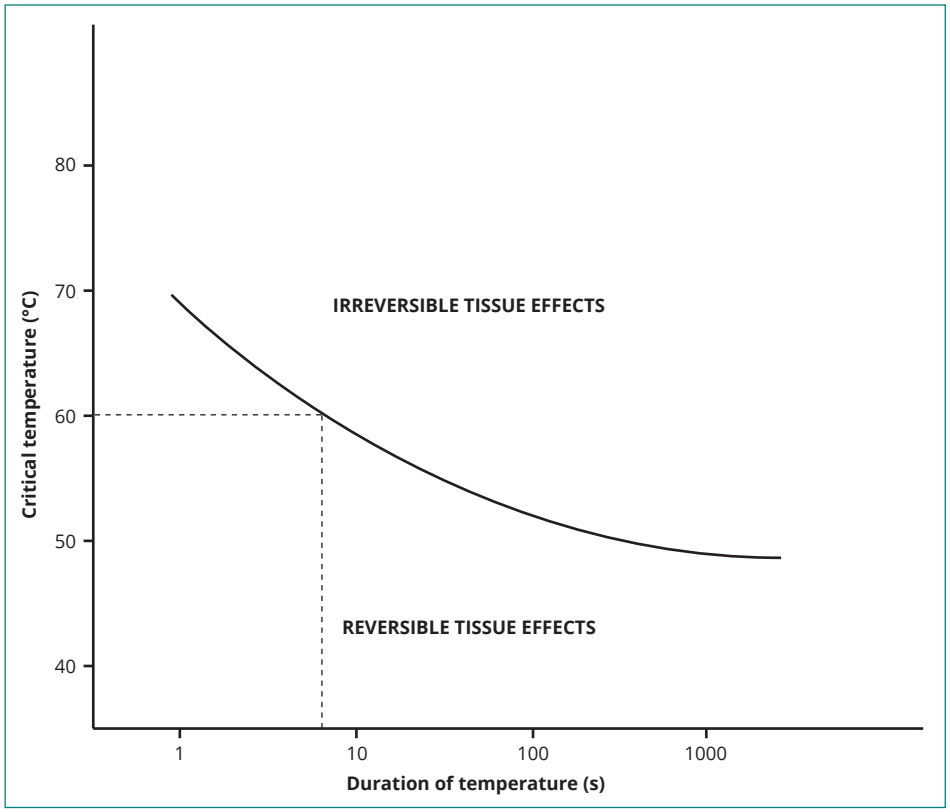

Figure 2
Critical temperatures for the occurrence of cell necrosis. Image from [1].

Successful Management of Diabetic Peripheral Neuropathic Pain Using MiS MLS® Laser Therapy: A Case Report.

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INTRODUCTION

Neuropathic pain (NP) is a particularly severe form of chronic pain, arising as a direct consequence of a lesion or disease affecting the somatosensory nervous system[1]. This condition is the result of a series of different pathological mechanisms, and it is usually described based on the anatomic localization or etiology. The conditions and the pathophysiological states that determine the onset of neuropathic pain mostly involved are metabolic disorders (e.g. peripheral diabetic neuropathy), neuropathies associated with viral infections (e.g. post-herpetic neuralgia, HIV, leprosy), autoimmune disorders affecting the central nervous system (e.g. multiple sclerosis and Guillain–Barre syndrome), chemotherapy-induced peripheral neuropathies, damage to the nervous system of traumatic origin (e.g. spinal cord injury and amputation), inflammatory disorders, hereditary neuropathies, and channelopathies[2].

Estimates of NP in the general population suggest the prevalence is 7% to 10%[3], increasing to around 20% to 30% in people with diabetes[4]. Studies have also reported greater prevalence of neuropathic pain, as with chronic pain overall, in older people, women, and people from areas of high social deprivation[5].

The principal clinical signs associated to NP are allodynia (pain due to a stimulus that does not normally provoke pain), hyperalgesia (an increase in the perception of pain generated by a stimulus that causes pain) and paresthesia (a condition that determines the perception of anomalous sensations comparable to needle bites, tingling, itching, reduced, or even loss of sensitivity). In patients suffering from NP, the perceived pain is usually spontaneous, manifesting itself without needing a stimulus. This pathological condition substantially affects the quality of life of patients, compromising their psychological state[6].

It is important to distinguish NP from other forms of pain which arises from actual or threatened damage to non-neural peripheral tissue. NP is generally unresponsive to analgesics such as nonsteroidal anti-inflammatory drugs (NSAID) or opioids. Rather, gabapentinoids, tricyclic antidepressants, and serotonin–norepinephrine reuptake inhibitors are recommended as first- and second line treatments[7].

Nonetheless, these medications for NP provide greater than 50% pain relief in less than half of people treated. Furthermore, analgesics in general, particularly opioids and gabapentinoids, can potentially cause harm, providing an even greater emphasis on appropriate use[8].

Peripheral neuropathic pain (PNP) is a direct consequence of a lesion or disease affecting the peripheral nerves. There are two main types of PNP. The pain experienced in the nerve trunk is a result of chemical or mechanical insults to sensitized nociceptors in the nervi nervorum. This pain can have a deep aching quality and often approximates the course of the involved nerve. Dysesthetic pain, on the other hand, is a consequence of damaged or regenerating neuronal fibers. It can have an electrical, burning, or launching quality. Finally, a combination of both types could occur.

PNP is typically worsened by activities that compress or stretch the involved nerves. The signs of PNP include pain with active and passive range of motion of the involved limb; tenderness to palpation of the involved nerve; tenderness or inflammation of the tissue innervated by the involved nerve[9].

The management of PNP mostly require a multidisciplinary approach

based on medication[10]; cognitive-behavioral therapy[11] to reduce distress and worrying thoughts; education regarding peripheral nerve physiology; gentle movement without undue tension on the nerve bed to help restore the endoneurial circulation; treatment of the local dysfunction affecting the nerve / manual therapy; physical agents that gate the sensation of pain such as electric stimulation, cold or heat[12].

Among physical therapies, laser therapy has emerged as a promising approach for the management of peripheral neuropathies. However, the efficacy of laser therapy in treating peripheral neuropathies remains a subject of ongoing study and debate. Some studies have suggested that laser therapy may be beneficial in improving the symptoms of peripheral neuropathies, primarily through its anti-inflammatory, analgesic, and tissue healing-promoting effects. The theory proposes that laser light may stimulate cellular metabolism, increase local blood flow, and reduce inflammation, thereby contributing to the alleviation of neuropathic symptoms. Nevertheless, the results of studies on laser therapy for peripheral neuropathies are inconclusive, with some studies demonstrating significant benefits while others have not. Factors influencing the efficacy of laser therapy include the duration of treatment, the power of the laser used, the type of neuropathy, and the severity of symptoms.

The following clinical case presents the use of a particular type of therapeutic laser, the multiwave-locked system (MLS®) laser, at high power ($P_{average}$>500mW). This system spatially and temporally combines two wavelengths, 808nm and 905nm, with programmable emission in continuous/frequency-modulated mode for 808nm and pulsed mode for 905nm.

Previous clinical evidence indicates that lasers belonging to the MLS® family have been effective in the treatment of diabetic polyneuropathies[14-17].

In this case report, the MiS laser device was utilized. This laser belongs to the MLS® family of devices, and it is distinguished by a maximum peak power of 1 kW and maximum average power of 6W± 20%, which enables the safe targeting of deeper tissue layers, a common site of neuropathic pain onset.

In a pre-clinical study, Micheli et al.[18], through a model of sciatic nerve chronic constriction in the rat, that mimics the neuropathic pain, demonstrated that the treatment with MLS®-MiS laser therapy reduced pain significantly and protected nerve structure through different mechanisms. This included inhibition of the enzymes involved in the inflammation process, myelin sheath restoration, and modulation of pain-stimulating signaling at the central nervous system level.

In a preliminary clinical experience, Mezzalira et al.[19] tested the safety and efficacy of MiS laser in a group of patients suffering of peripheral neuropathy of different origins, obtaining an average pain reduction of 79.5%.

Based on its characteristics and the previous evidence on mechanism of action and clinical effects, the MiS laser was considered a valid device to treat neuropathic pain in diabetic polyneuropathies.

CLINICAL CASE

The patient is a 67-year-old female with a diagnosis of type II diabetes mellitus in 2008 and ongoing insulin therapy since 2014. She also has bilateral coxarthrosis and gonarthrosis on the right side. The patient was suffering of pain, numbness and burning feeling in the legs and feet since 2019 for the right side and since 2020 for the left side. In October 2022 a distal sensorimotor polyneuropathy of the lower extremities was diagnosed. The EMG exam presented an axonal degeneration and a partial segmental demyelination, more pronounced for sensory fibers. The patient reported a loss of skin sensibility at the lateral aspect of the left thigh.

In November 2023, the patient decided to undergo a cycle of laser therapy due to the persistence of severe pain despite the previous uneffective medical treatment (NSAIDs, analgesics and rest).

MATERIALS AND METHODS

The patient was evaluated through the Neuropathic Pain Symptom Inventory (NPSI) which is a scale approved for valuating both peripheral and central neuropathic pain[13]. NPSI is used to aid in the diagnosis of certain subcategories of neuropathic pain syndromes and to help determine beneficial treatments. The scale ranges from zero to 10, with zero being no pain at all and 10 being the worst imaginable pain. The total scores of all ten descriptors are added to find the total pain intensity. Each descriptor may be observed separately to evaluate different types of pain in isolation. Sections of the scale include the evaluation of the severity of spontaneous pain, painful attacks, provoked pains, and abnormal sensations.

The patient underwent to a cycle of MLS® laser treatments, with MiS device: 3 sessions per week, every other day, for two weeks. The handpiece was equipped with a lens of 2 cm of diameter and spot area of 3.14 cm^2.

During each session, the laser was initially applied in scan mode along the dorsal and the plantar aspects of both feet (total area treated per foot ≈ 200 cm^2) - Fig. 1.

Subsequently, during the same session, each lower limb was treated in fixed mode. The following areas were treated for each limb: four along the posterior aspect of the foot, four along the plantar aspect of the foot, and two along the deep fibular nerve - Fig 2.

The parameters used in the two stages, depending on the method of application, are reported in Table 1.

The selection of parameters and the application methodology are based on a synthesis of literature data, the setting proposed by the device, and previous experience.

RESULTS AND CONCLUSION

The patient reported no pain, numbness and burning feeling in the legs for the left leg after the fourth session while for the right leg after the fifth session.

At the end of laser therapy cycle the loss of skin sensibility at the lateral aspect of the left thigh was improved and the zone has diminished in size.

After the last treatment session, the patient's pain sensations were evaluated through the NPSI score. The total NPSI score resulted decreased of 70%, from 67/100 to 20/100 after 6 laser sessions in two weeks. NPSI scores, before and after MLS® laser treatment, are reported in Table 2.

At the follow-up examination one month later, the improvement remained.

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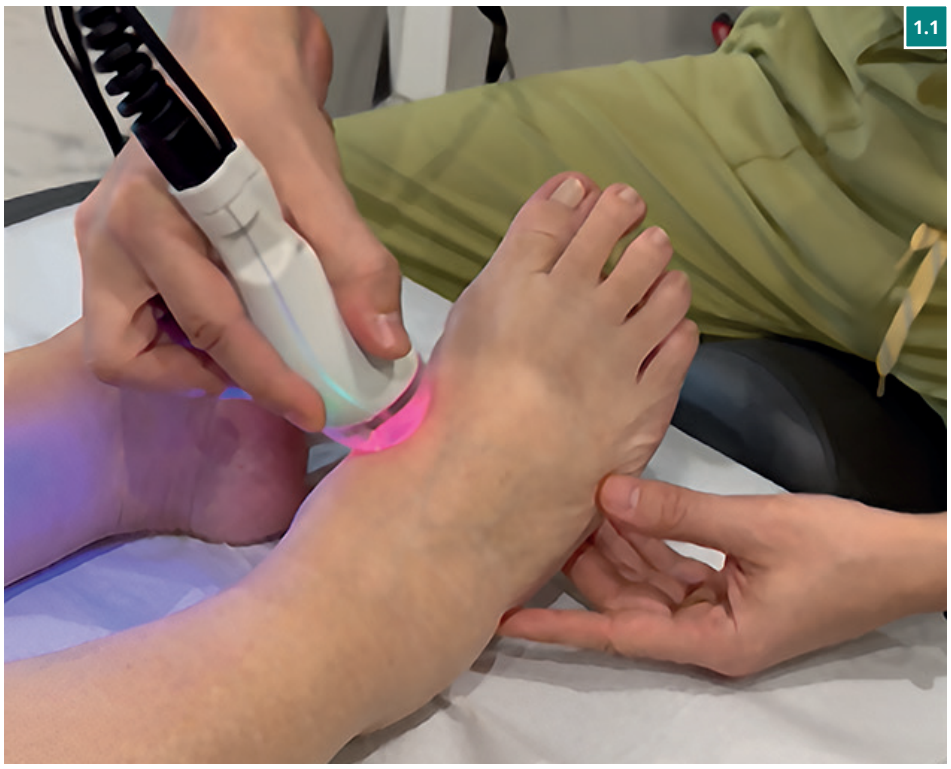
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Figures 1.1, 1.2
First Phase - Scanning of the dorsal and the plantar aspects.

MODALITY	FREQUENCY (Hz)	INTENSITY (%)	ENERGY (J)	DOSE (J/cm²)	DURATION (min:sec)
Scan mode	30	60	999.68	~ 5.0	08:06
Fixed mode	10	30	6.74	2.25	00:07 (per point)

Table 1
Different settings used during each treatment session.

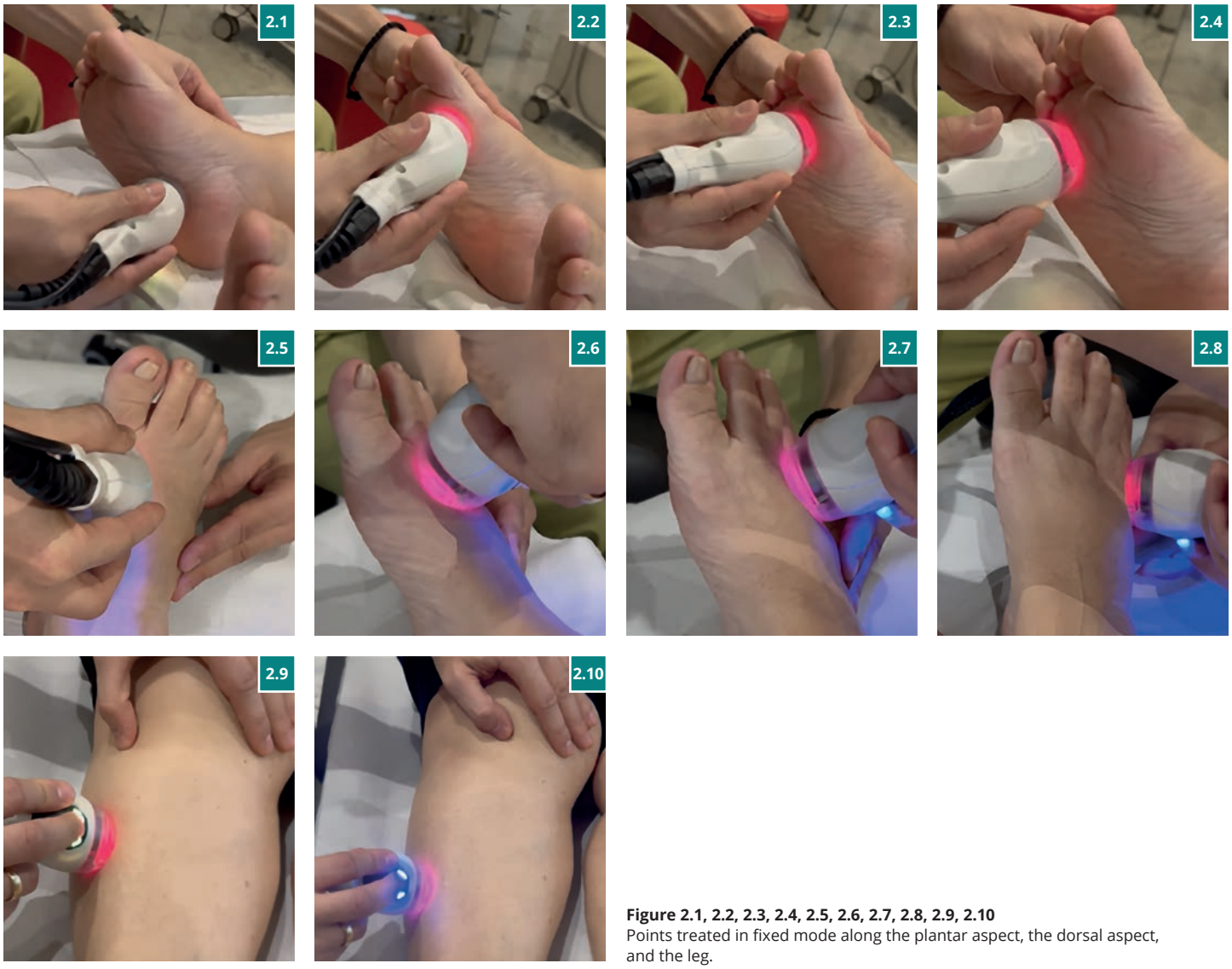

Figure 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 2.10
Points treated in fixed mode along the plantar aspect, the dorsal aspect, and the leg.

NEUROPATHIC PAIN SYMPTOM INVENTORY (NPSI)	BEFORE	AFTER	REDUCTION (%)
Severity of the Spontaneous Pain			
Q1. Does your pain feel like burning?	10	4	60%
Q2. Does your pain feel like squeezing?	7	3	57%
Q3. Does your pain feel like pressure?	9	3	66%
Q4. During the past 24h, your spontaneous pain has been present: permanently / 8 to 12 h / 4 to 7 h / 1 to 3 h / < 1h	permanently	4 to 7 h	
Severity of the Painful Attacks			
Q5. Does your pain feel like electric shocks?	0	0	-
Q6. Does your pain feel like stabbing?	8	0	100%
Q7. In the past 24 h how many of these pain attacks have you had? >20h/11 to 20/ 6 to 10/ 1 to 5/ none	1 to 5	None	
Severity of your Provoked Pains			
Q8. Is your pain provoked or increased by brushing on the painful area?	8	3	62.5%
Q9. Is your pain provoked or increased by pressure on the painful area?	5	3	40%
Q10. Is your pain provoked or increased by contact with something cold on the painful area?	0	0	-
Severity of Abnormal Sensations			
Q11. Do you feel pins and needles?	10	2	80%
Q12. Do you feel tingling?	10	2	80%
Subscores			
1. Burning (superficial) spontaneous pain: Q1	10	4	60%
2. Pressing (deep) spontaneous pain: (Q2+Q3)/2	8	3	62.5%
3. Paroxysmal pain: (Q5+Q6)/2	4	0	100%
4. Evoked pain: (Q8+Q9+Q10)/3	6.5	2	69%
5. Paresthesia/Dysesthesia: (Q11+Q12)/2	10	2	80%
Total intensity score			
1. Q1	10	4	60%
2. (Q2+Q3)	16	6	62.5%
3. (Q5+Q6)	8	0	100%
4. (Q8+Q9+Q10)	13	6	54%
5. (Q11+Q12)	20	4	80%
Total: (1+2+3+4+5) /100	67 / 100	20 / 100	**70%**

Table 2
NPSI scores before and after the treatment.

MLS® Laser Therapy for the management of a non-healing venous leg ulcer: A Case Report.

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INTRODUCTION

Venous leg ulcers are chronic wounds that usually develop on the lower leg, particularly around the ankle, due to compromised blood circulation (Brem H. et al., 2004). They are the most common type of chronic leg injury, accounting for 70-90% of all lower limb ulcers (Snyder RJ.,2004). Venous insufficiency, a condition in which the veins in the legs fail to efficiently return blood to the heart, is the cause of these ulcers. Blood pooling in the lower legs can cause increased pressure in the veins and eventual damage to the surrounding tissues, resulting in ulcer formation. The prevalence of this condition increases with age, with 60% of patients developing their first ulcer after the age of 50. Women outnumber men about 2:1, but before the age of 40, men are more likely to be affected. Venous leg ulcers present as open sores on the lower leg, often accompanied by discolored, swollen, or hardened skin. Pain and fluid drainage may also occur. If left untreated, these ulcers can become chronic and result in complications such as infection and impaired mobility. Treatment for venous leg ulcers usually involves addressing the underlying venous insufficiency and promoting wound healing. Compression therapy, wound dressings, leg elevation, lifestyle changes (such as exercise and weight management), and, in some cases, surgery or other interventions may be necessary to repair or remove damaged veins.

At The Hills Foot Clinic, a podiatric center where I have been working for the last 25 years, we treat leg ulcers according to standard Australian guidelines (Sinha S., & Sreedharan S., 2014). We follow a standard protocol to improve wound healing in various conditions, which includes management with a general practitioner, debridement, medication, and dressing.

To improve patient care at The Hills Foot Clinic, we evaluated the use of laser therapy as an adjunctive treatment for the management of chronic venous ulcers.

The clinic was already using a laser with near-infrared wavelengths (808nm + 905nm). The Multiwave Locked System (MLS®) laser therapy was frequently used to rehabilitate patients with musculoskeletal problems such as osteoarthritis, Achilles tendonitis and plantar fasciitis.

Therefore, based on clinical evidence of the mechanism of action of MLS® Laser Therapy (Micheli L. et al., 2019; Monici M. et al., 2013; Genah S. et al., 2021) and its proven analgesic, anti-inflammatory and tissue repair modulating effects, we decided to explore its integration into standard care for the treatment of chronic venous ulcers. The results of this evaluation were promising.

Presented below is a clinical case in which the MLS® laser treatment was used as an adjuvant treatment to improve wound healing in the management of a chronic venous leg ulcer.

MATERIALS AND METHODS

The MPhi 5 device (ASA Srl, Italy) was used to apply MLS® Laser Therapy, which is a class IV laser therapy system capable of emitting near-infrared (NIR) beams with wavelengths of 808 nm - 905 nm. The beams are spatially overlapped and synchronized, with continuous (or frequenced) and pulsed emission respectively. The system has an average power of 1.1W and a peak power of 25W.

The device has a multi-diode head that enables fixed or manual scanning of the anatomical area to be treated with homogenous energy delivery. The spot area is 19.6 cm^2. Additionally, the device is equipped with a handpiece for close-to-skin application with a spot area of 3.14 cm^2.

CASE REPORT

In August 2022, a 69-year-old woman with a history of varicose eczema, diabetes, and chronic psoriasis, along with dermatological and arthritic manifestations, visited The Hills Foot Clinic due to a chronic venous ulcer on her left medial lower leg.

The patient reported limited mobility and the need for a walker or cane to ambulate.

From November 2021, the ulcer was managed by a home nurse who changed the dressings once a week. However, it gradually worsened until February 2022 when the patient was hospitalized. Cultural tests revealed a Pseudomonas aeruginosa infection. The patient received intravenous antibiotic therapy and local antiseptic dressings. After a week, the patient was discharged, and bi-weekly dress changes and medication were prescribed.

Despite undergoing new treatment therapy, the patient's ulcer condition did not improve over the following six months. In fact, the pain worsened and became increasingly difficult to manage, necessitating the use of opioid oxycodone (Endone). This medication severely impacted the patient's daily life, as it interfered with her ability to sleep and concentrate.

In patient's words: "The home nurse came but the ulcers gradually got worse. I had to go to hospital. They put me on intravenous antibiotics. After seven days I returned home and then the wound clinic nurse came twice a week to dress them and treat them. They put heavy compression stockings on, and my ulcers got worse. I was crying with the pain and the frustration. I couldn't do anything. I've got animals. I would feed the animals, take the Endone, wait for it to kick in and then come inside and just put my legs up. I had no help. I'm on my own."

Standard therapy (debridement, medication, and dressing) was combined with MLS® laser treatment to reduce pain and promote healing.

The laser treatment was initially applied every other day, for the first 4 weeks. Due to visible signs of healing, the treatment was then reduced to once a week for a total of 10 treatment sessions over 48 days.

The multi diode head was used to apply laser treatment at approximately 20 cm from the skin (Figure 1). This was done after removing necrotic tissue and before administering medication and dressing. Both the patient and the doctor wore appropriate laser safety goggles.

During each session was treated the ulcer's area and the surround tissues. The device parameters were set as reported in Table 1.

During the initial treatment visit on August 18th, 2022, the ulcer presented an area of approximately 15 cm^2 (3 cm x 5 cm) - Figure 2.1. By the end of the visit, the patient reported a significant reduction in pain, which allowed her to discontinue the use of Endone. The analgesic effect was sustained throughout the treatment cycle, enabling the patient to cease taking opioids.

During treatment, the wound showed improvement with a progressive reduction in the superficial area, formation of granulation tissue, and reduction of exudate. The surrounding tissue inflammation also improved as the oedema gradually disappeared (see Figure 2.2-2.6). By the fifth visit, the ulcer area had reduced by more than 50% (2cm x 1cm).

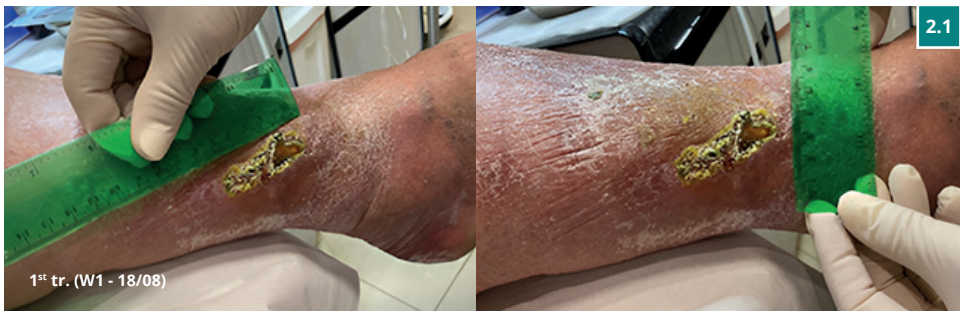
Figures 1.1
Example of the MPhi 5 multidiode head in action during a laser treatment session. The red light 635nm-68nm is used as a pointer, it has a maximum power of 1 mW and no therapeutic effects.

During the seventh visit, the patient reported a small trauma in the ulcer area, which appeared to have regressed. During a dressing change, green exudate was noticed. Due to discoloration at the edges of the ulcer, a recurrence of infection was suspected. The patient was sent to a general practitioner who prescribed a swab and preventive antibiotic treatment with Ciprofloxacin. After 5 days, the swab analysis showed no signs of infection, and the antibiotic therapy was stopped.

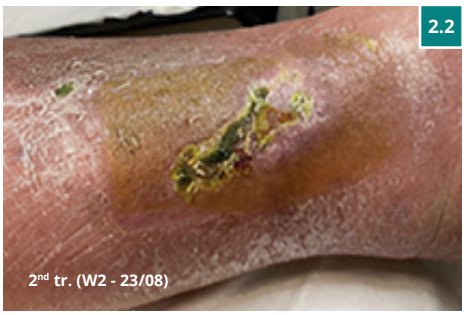
At the 9th MLS® laser treatment, the remaining wound appeared significantly smaller, with a superficial area of approximately 0.45 cm^2 (0.9 cm x 0.5 cm) - Figure 2.9. After 48

AREA (cm^2)	FREQUENCY (Hz)	INTENSITY (%)	TOTAL ENERGY (J)	DOSAGE (J/cm^2)	TIME (min:sec)
100	1500	100	798	7.98	08:00

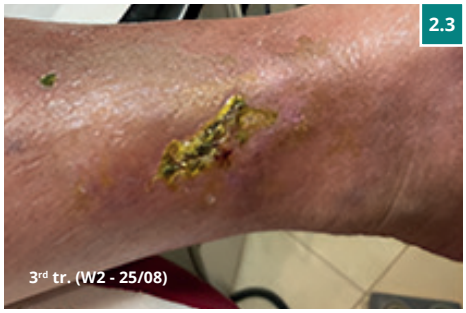
Table 1
Setting used during each treatment session.



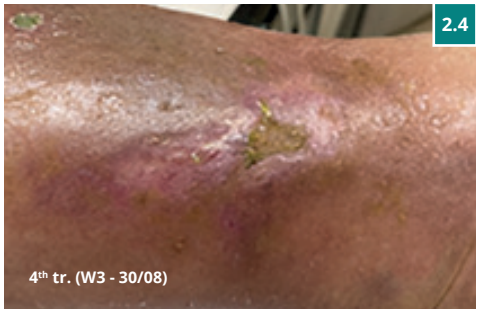
Figures 2.1
Baseline visit, ulcer condition before debridement and first laser treatment.



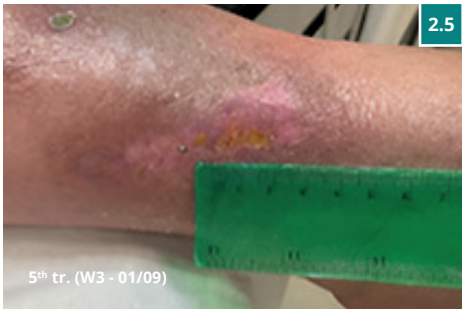
Figures 2.2
Ulcer condition before removing necrotic tissue.



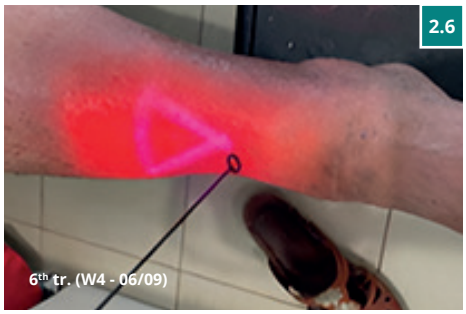
Figures 2.3
Ulcer condition after debridement and 3rd MLS® laser treatment.



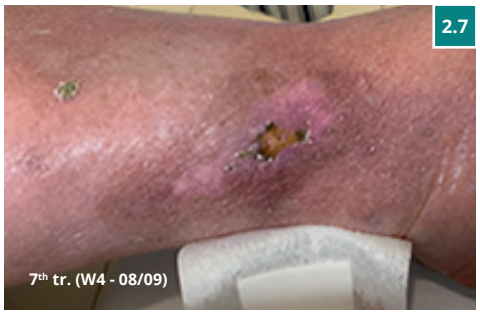
Figures 2.4
The ulcer present depth reduced and eschar lifting with minimal scarring and surrounding skin much improved with significant reduction in leg's oedema.

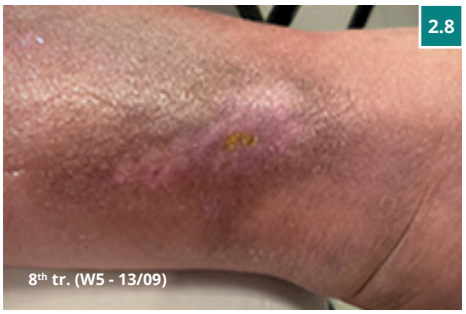


Figures 2.5
In occasion of the 5th visit the ulcer appear with a granulating base, no exudate, and a superficial area of ~ 2cm^2.

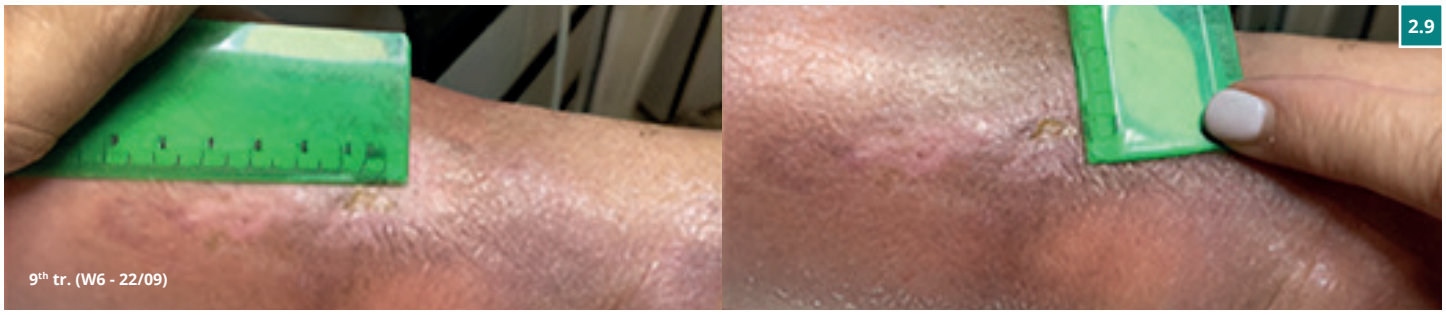


Figures 2.6
Application of the MLS® laser during the 6th treatment, detain on the spacer used to maintain 20 cm distance from the skin.





Figures 2.7, 2.8
Ulcer regression due to a small trauma.



Figures 2.9
Ulcer condition after 5 weeks since the first treatment, superficial ulcer's area of 0.45cm^2.

days and 10 MLS® laser treatments, the ulcer had closed, the quality of the surrounding tissue improved and there was no oedema.

The patient was discharged with the only prescription to wear an elasticated tubular bandage for mild compression and protection of the fragile new skin.

No side effects were reported, and the satisfaction of the patient was high.

Patient said: "Look, for me, it was a miracle. I could not believe it. The ulcer is now totally fine. It is all clear. It was worth it. I'd do anything to get out of that pain. I could not stand it".

DISCUSSION AND CONCLUSION

Based on our clinical experience, the integration of laser therapy with traditional therapies is feasible and has been shown to promote and accelerate the healing process, particularly in chronic ulcers.

These results are consistent with previous in-vitro studies and clinical cases involving similar problems, such as non-healing wounds and post-surgical ulcers in diabetes patients, always treated with MLS® Laser Therapy (Vignali T. et al., 2021; Tedeschi A. et al., 2023).

This Case Report provides additional evidence on the potential restorative effects of MLS® Laser Therapy. However, randomized clinical trials are necessary to validate its application in treating chronic venous ulcers.

Note: all the photos reported have been given with patient's permission.

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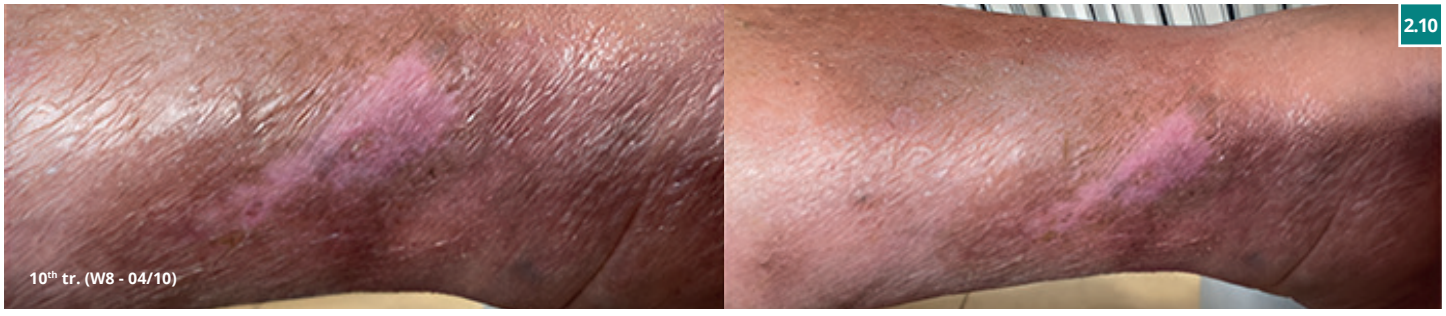


Figures 2.10
Last treatment, the ulcer seams completely closed, surrounding skin quality improved and no oedema.

Effects of electromagnetic therapy in multiple traumatic dog: A Case Report.

Kanogwan Kimram[1], Naruemon Plongthong[1], Warangkana Promsatit[1], Napat Kaewduangjai[1], Pakawan Asawawongsawat[1]

[1] Intensive care unit, Kasetsart University Veterinary Teaching Hospital, Faculty of Veterinary Medicine, Kasetsart University, Bangkok, Thailand

INTRODUCTION

Traumatic condition in critical cases have a strong ongoing relationship. Magnetic therapy is one of the non-invasive complementary therapies. It is a safe, and easy method to directly treat the site of injury, the source of pain and inflammation, and other types of disease. Magnetic therapy was applied to promote bone healing (1), treat osteoarthritis (2) and inflammatory diseases of the musculoskeletal system (3), alleviate pain, and may have benefits to enhance healing in traumatic cases.

The purpose of this case report was to describe the positive outcome to use the electromagnetic therapy for complementary rehabilitation therapies with conventional treatments of a dog in multiple trauma conditions.

CASE REPORT

This case study involves a 5-months-old, intact male Golden Retriever dog presented with tetraparesis, seizure and comatose by a car accident 5 days ago. Physical examination presented unconsciousness, tetraparesis, tachypnea, right temporomandibular joint (TMJ) luxated and crepitus of left humerus. Neurological examination was localized to cerebral cortex and brain stem lesions. The Modified Glasgow Coma Scale (MGCS) was 3. Laboratory tests revealed anemia of 23.1% (reference range, 35-45%), leukocytosis of 19.09 x 103/µL (reference range, 5-14.1 x 103/µL). Radiography was presented to skull fracture, lung hemorrhage (Figure 1) and left humerus fracture (Figure 2).

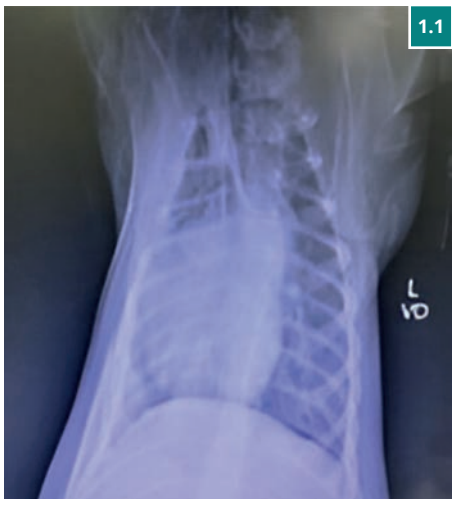
CT scan of skull is preferred for evaluate bone fractures and identify areas of acute hemorrhage or edema. CT scan showed multiple sites of skull fractures, right maxilla, both frontal, right zygomatic, right caudal mandible, right caudal zygomatic, right temporal, left occipital bone (Figure 3) and patchy small area of hyper-attenuation at the cranial of midbrain in pre-contrast study (Figure 4), no detectable mass effect, hypo-attenuated of large edematous parenchyma in the brain, right temporomandibular joint is displacement (Figure 5) and left tympanic bulla shows partial ventral fluid-filled.

CT skull presented to multiple skull fractures, brain edema, midbrain hemorrhage and right TMJ luxation.

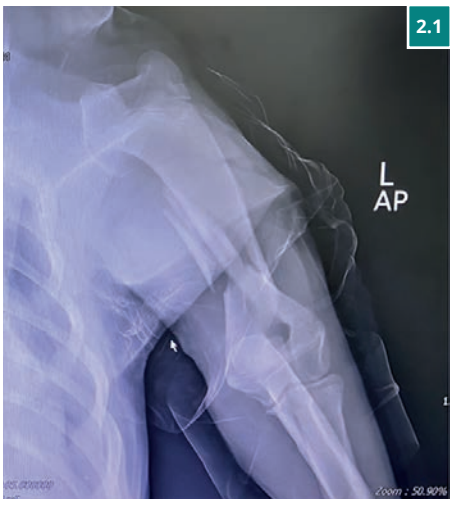
Brainstem auditory evoked response (BAER) was performed under coma conditions presented to both intact brain stem activity and decreased amplitude at left brain stem.

MATERIALS AND METHODS

The treatment plan focused on maintaining vital signs through supportive care, including pain medication, an-

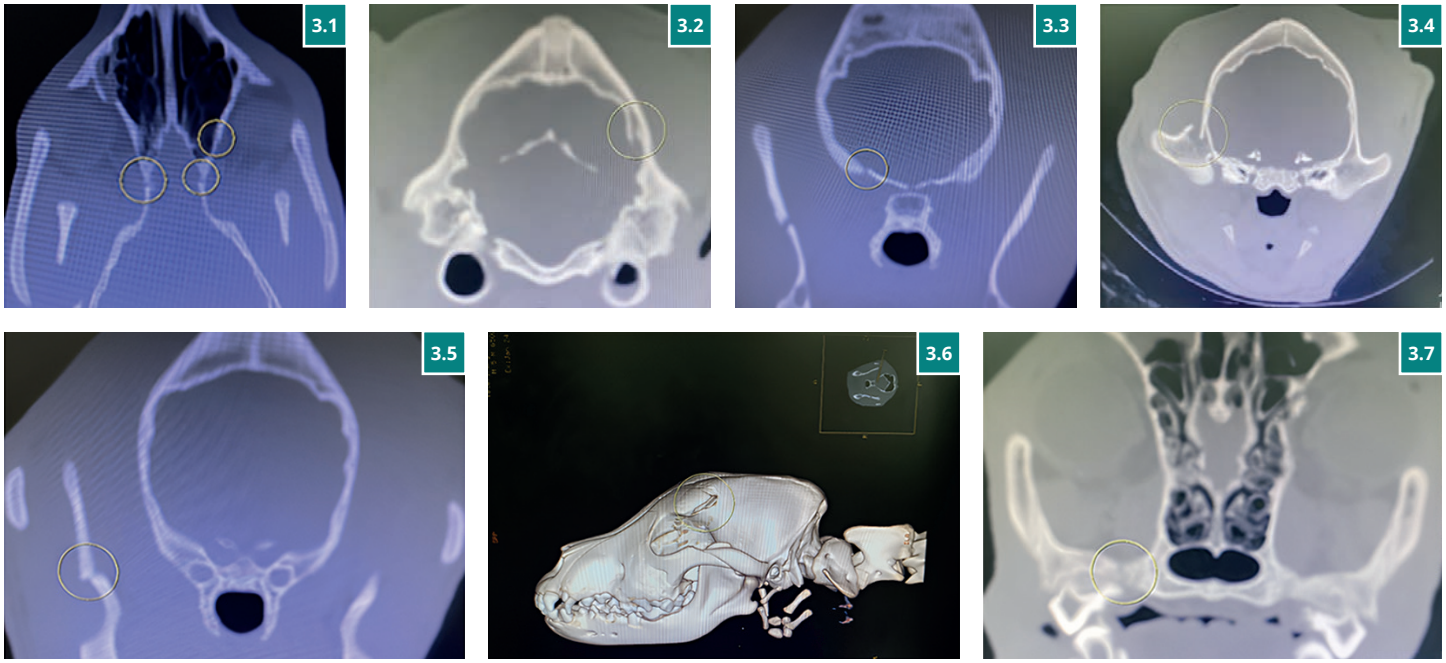


Figures 1.1
Lung hemorrhage.



Figures 2.1
Left humerus fracture.

Figures 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7
Figures show multiple sites of skull fractures, right maxilla, both frontal, right zygomatic, right caudal mandible, right caudal zygomatic, right temporal, left occipital bone.



tiepileptic drugs, antibiotics, oxygen supplements, and blood transfusions.

Surgery was not an option due to the high risks associated with general anesthesia.

After three days of treatment, electromagnetic therapy was added. The patient received pulsed electromagnetic field (PEMF) therapy twice a day using the PMT QS device (ASA Srl, Arcugnano, Italy), using the portable solenoid applicator (Ø-50cm), following the neuromuscular disease pre-set protocol (Frequency: 25 Hz, Intensity: 15%, Treatment duration: 20 min, Magnetic flux density: ~7.5 G).

RESULTS AND CONCLUSION

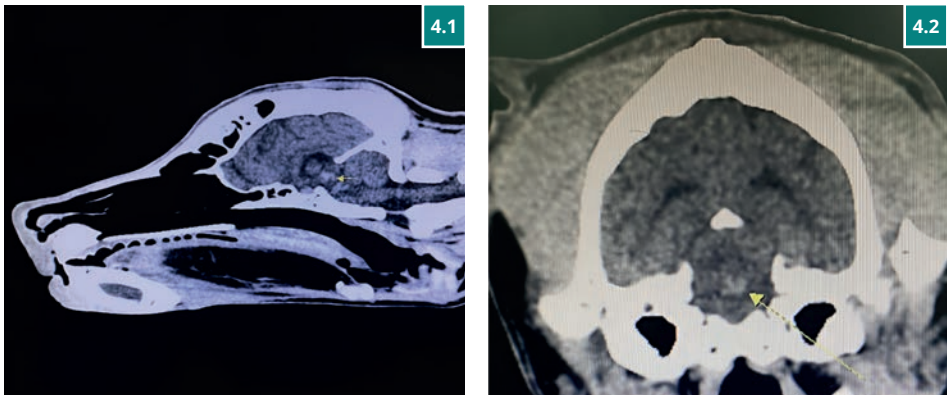
After 3 days of electromagnetic therapy, the patient's MGCS improved, and he began eating independently.

The patient was discharged from the intensive care unit after one month, exhibiting an overall improvement in clinical and neurological signs, as well as a Modified Glasgow Coma Scale (MGCS) score of 14. (Figure 6)

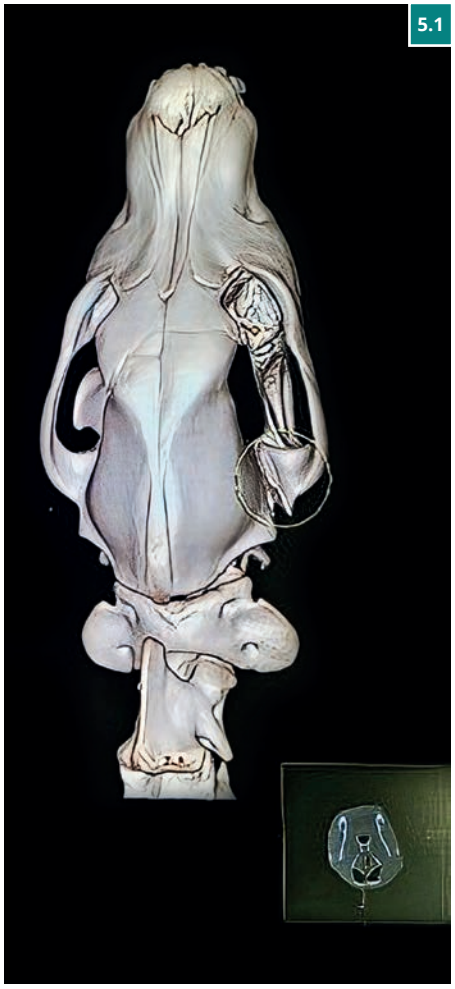
Subsequently, the left humerus underwent callus formation at the fracture site (Figure 7), thereby enabling the patient to regain ambulatory capacity and consciousness.

In conclusion, the use of electromagnetic therapy as a complementary treatment for multiple organ trauma and traumatic brain injuries with low MGCS has been demonstrated to be an effective approach. Therefore, this may represent a novel approach for critical care patients with complex conditions that are refractory to conventional therapy.

One advantage is that the treatment is safe and does not disrupt the delicate physiological state of the patient.

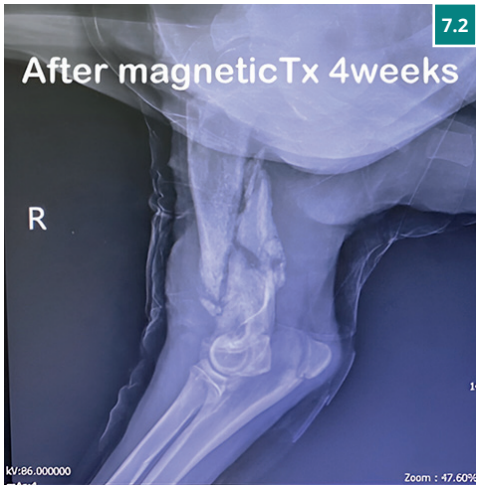


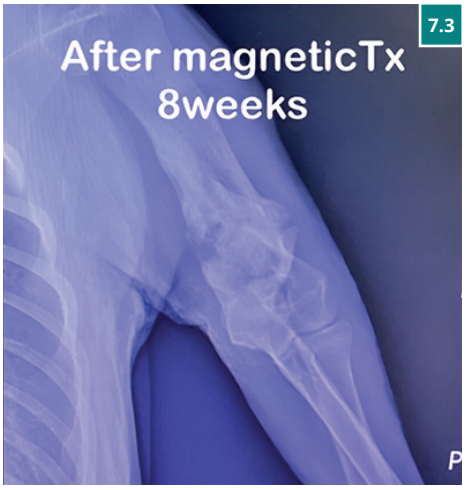
Figures 4.1, 4.2
Patchy small area of hyper-attenuation at the cranial of midbrain in pre-contrast study.



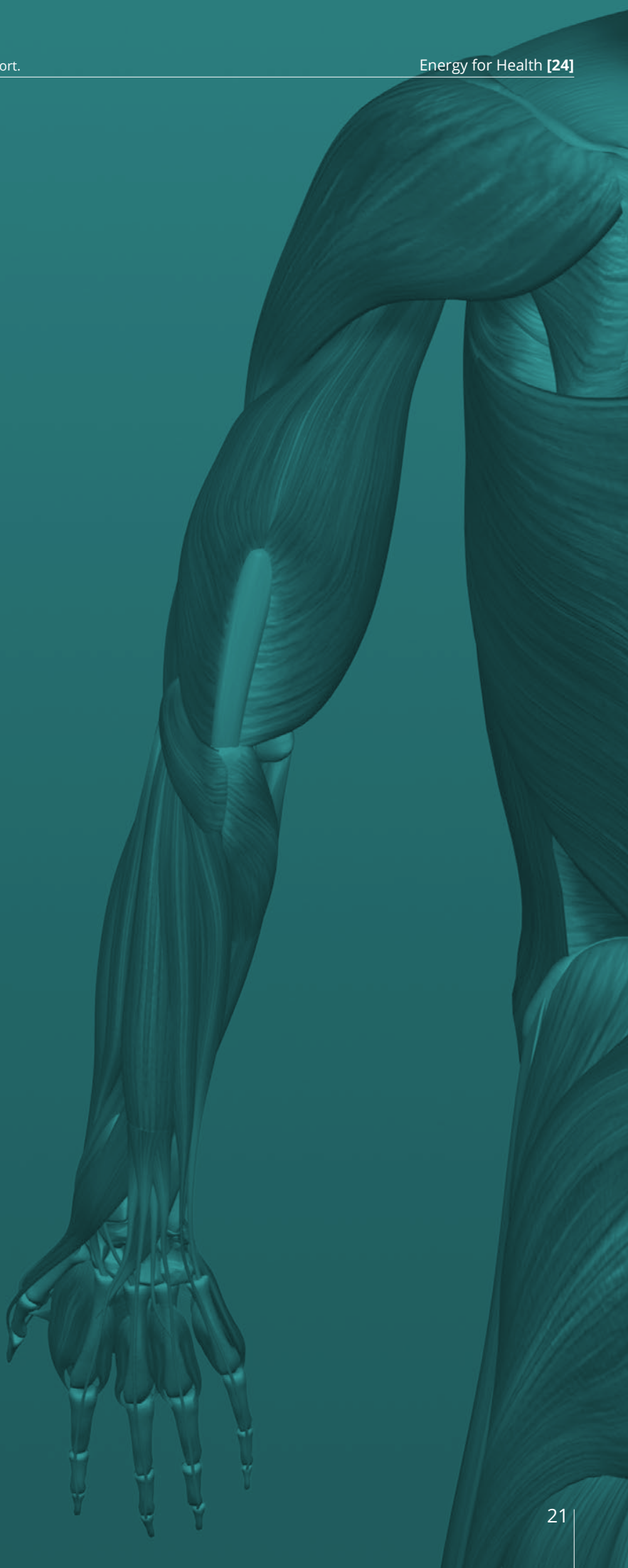
Figures 5.1
Right temporomandibular joint displacement.

Figures 6.1, 6.2, 6.3, 6.4
Clinical condition of the subject at baseline, during a PEMF session, along hospitalization and at discharge visit.





Figures 7.1, 7.2, 7.3
Fracture evolution during the PEMF treatment.



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Guide for Authors

The aim of "Energy for Health" is to spread the results of research on the application of laser and magnetic field in biology and medicine. The journal will publish studies which involve basic research and clinical trials: laser-tissue interaction, effects of laser and electromagnetic field on cells.
Attention will be focused on studies devoted to explain the molecular and cellular mechanisms at the basis of the effects produced by laser and magnetotherapy.

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Articles are full-length papers presenting complete descriptions of original research, which have not been published and are not being considered for publication elsewhere.

Letters to the editor will be accepted and published if considered pertinent to the aim of the journal by the editorial board.
Reviews are topical overviews on emerging areas of research. They summarize key problems, concepts, experimental approaches, and research opportunities that characterize a subject area. Reviews should not include previously unpublished research results. The Editors generally invite them; authors who wish to submit a review should first consult with the Editors.

Case Reports will be considered if they present data with relevant clinical significance. Case Reports will be accepted if formatted as a research letter with 2 figures maximum, maximum length is up to 1000 words with up to 6 references and 2 tables or figures. There should be no Abstract and no headings.

MANUSCRIPT SUBMISSION
To keep the review time as short as possible, the authors are requested to submit manuscripts (both text and art) in electronic form to the executive editor of "Energy for Health", Dr. Monica Monici, using the following e-mail address: monica.monici@asalaser.com. Manuscripts submitted via any other method will be returned. The manuscript must be accompanied by a cover letter outlining the significance of the paper. Authors are requested to read carefully the instructions (also available at the web site www.asalaser.com) and to follow them for the preparation of their manuscript.

PREPARATION OF MANUSCRIPTS
Manuscripts must be written in clear, concise, grammatical English. Authors unfamiliar with English usage are encouraged to seek the help of English-speaking persons in preparing their manuscripts. Manuscripts should be double-spaced.

TITLE PAGE
The title page (page 1) should include:
- A concise and informative title (capital bold font; not exceeding 120 characters)
- The name(s) of the author(s) (lower-case bold font, initials in capital letters)
- The affiliation(s) and address(es) of the author(s) (italics font)
- The name of the corresponding author, with complete address, e-mail address, telephone and fax numbers

ABSTRACT
Each paper must be preceded by an abstract (page 2) that summarizes in no more than 250 words a brief introduction, the aim of the study, materials and methods; main results and conclusions. It shouldn't contain any reference.

KEYWORDS
After the abstract, in the same page, a list of 4-6 keywords should be supplied for indexing purposes.

INTRODUCTION
The introduction should describe the state of the art, give a short review of pertinent literature, state the purpose of the investigation. It should be as concise as possible, without subheadings.

MATERIALS AND METHODS
The "materials and methods" section should follow the introduction and should provide enough information to enable the experiments to be reproduced.
Patients (clinical studies): typology of patients (age, sex....), criteria for enrolment in the study, etc.
Experimental model: cellular, animal, etc.
Instruments: laboratory instruments used for the research.
Methodology: protocols and evaluation mode.
"In the case that laser sources are considered, authors are requested to specify all the necessary technical data pertinent to the experiment(s): laser type and wavelength, emission mode (continuous, pulsed), laser power (peak and average power in case of pulsed emission), laser beam dimensions, beam intensity (Watt/cm^2 spot area), total energy dose on the irradiated area in a single treatment (J/cm^2), duty cycle. In case of laser treatment of cultured cell models, as well as in vivo and ex vivo treatments, authors are requested to specify the dimensions of the treated region, treatment duration and timing modalities (e.g. one session, multiple sessions)."
Data analysis: data-analysis method, statistical analysis.

RESULTS
This section should describe the outcome of the study without any comment. Data should be presented as concisely and clear as possible.

DISCUSSION
The discussion should be an interpretation of the results and their significance, also with reference to works by other authors. The relevance of the results in the research and clinical applications should be explained.

CONCLUSIONS
They should be concise and effective, with reference to possible involvements in the future.

ACKNOWLEDGEMENTS
Concise acknowledgements may be addressed to persons, public and private organizations, companies.

REFERENCES
Reference should be made only to articles that are published or in press. The list of references should only include papers that are cited in the text. They must be progressively numbered (in square brachets) in the order in which they appear in the text and listed at the end of the paper in numerical order. Each reference should cite article title and the authors. Abbreviations of journal titles should follow those used in Index Medicus.
References with correct punctuation should be styled as follows:

Reference to a journal publication:
1. Boyle WJ, Simonet WS, Lacey DL. Osteoclast differentiation and activation. Nature, 2003, 423: 337-342.

Reference to a book:
2. Michaeli W. Extrusion Dies. Hanser Publishers, Munich, Vienna, New York, 1984.

Reference to a chapter in an edited book:
3. Gmünder FK, Cogoli A. Effect of space flight on lymphocyte function and immunity. In: Fregly MJ, Blatteis CM, eds. Handbook of Physiology. Oxford:University Press, 1996, vol. 2, pp 799-813.

FIGURES
All figures should be cited in the text and consecutively numbered with arabic numbers. Figures should be exclusively in TIFF or JPG format, with a minimum resolution of 300 dpi. Figure legends must be brief, self-sufficient explanations of the illustrations and double spaced. The legends should be prepared in a separate file in rtf format.

TABLES
All tables should be cited in the text and consecutively numbered with roman numbers.
Each table should have a title and a legend (double spaced) explaining the table content and any abbreviation used. Each table should be prepared in a separate page.

ABBREVIATIONS
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