Laser And Physical Therapy Applied To Traumatic Central Nervous System Injuries: Update

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Introduction

Traumatic Central Nervous System Injuries (TCNSI) are not diseases but lesions that concern an ever growing number of people who have lost their independence and are unable to work. These persons need help to recover at least some of their functional abilities. Causes include traffic accidents, diving in shallow water, occupational accidents, war, falls, gunshots, stab wounds and natural disasters (earthquakes). Social aspect is highlighted by WHO in its definition of health , which is "not the absence of disease or infirmity but a state of complete physical, psychological and social wellbeing." Right indications are given in the International Classification of Functioning, Disability and Health, established by WHO in the year 2001. There is significant correlation of trauma epidemiology with the economic conditions of a community [1]. In USA, more than 10% of residents suffered from non fatal injuries in 2002. Trauma was the leading cause among those aged 1-4 years. In Germany, 40% of the injured were aged between 20 and 39 years in 2002 (greatest incidence between 20-24 years).

The beneficial effects of light on biological tissues have been known since Hippocrates time [2,3,4].

Around 1966, Mester et al. [5] were the first to point out that a red light laser stimulates hair re-growth in the coats of rats and halves the healing time of experimental ulcers. Many experiments have been done and proved incontrovertibly that visible and close to infrared wavelength lasers influence the healing time of skin wounds and ulcers, stimulating or inhibiting the process according to the radiation dosage and method. [6,7,8,9,10]. In 1998, researchers of Bethesda University (Maryland) demonstrated that, at specific doses, some lasers could increase cultured fibroblast activity by 98% [11]. Many, strictly dose-dependent effects have been demonstrated in nearly all normal and pathological biological processes: from cell maturation to reproduction, from inflammation to edema, from neural irritation to pain inhibition, and also through increased endogenous endorphin production. The importance of dosage in all these cases was immediately realized to be fundamental, because the same type of laser may have opposite effects on the same biological process and on the same tissues if the irradiation dose is modified. A good bibliographic critical review on this topic has been written by Tuner and Hode [12]. Many other uses of non-surgical laser were studied following this concept, as the modulation of metabolisms, immunological system, nerve cells functions, progenitor cells, light energy exchanges [10,12,13,17,20].

In terms of dosage, in order to obtain the desired effects, it is necessary to consider a whole series of physical parameters (Wavelength, Emission, Fluence, Energy Density, Repetition Pulse Frequency, Spot Size, Irradiation Time/Spot), biological factors (type of tissue, biological health) and clinical factors (irradiated point, number and rhythm of sessions, irradiation procedure) [7,8,9,10,13,18].

Therefore it is evident that, if the effects of light are dependent on small quantities of radiation and on how they are administered, it follows that we must use lasers which allow us to administer precise and selective doses to tissue. This is what is done in soft tissues regeneration, such as healing of skin wounds and ulcers, in the treatment of bone-muscle-tendon inflammations and traumas and neuralgias [11,12,13,14,15,16,18].

Regarding cellular level, Lubart et al. [17] demonstrated that lasers act on several components of the cell in a selective mode and according to the wavelength, affecting the mechanisms that produces water on mitochondria. This in turn triggers ATP production and immediately available energy, which stimulates cell function. It seems that, if the cell is damaged, the natural defense mechanism makes the mitochondria produce oxygenated water as opposed to “normal” water, so that cell cytoplasm is “cleaned” and can resume its normal function. If the damage is severe and irreversible, cell produces activated “singlet” oxygen, a cytocide substance which coagulates cytoplasm, preventing oncogenic and teratogenic transformations from taking place. All these mechanisms are influenced by luminous radiation in a strictly dose-dependent manner.

TCNSI represents a social problem today, interesting 5% of human population of economical developed countries. It is understandable that scientists, researchers, clinicians, health economists and planners are concerned with TCNSI and try their best to control it through more effective, easier and cheaper methods.

Regarding the effects of lasers on central nervous system, several authors (18,19,20,21,22,23,24,25,26) have demonstrated in vitro that, at given doses, some lasers regenerate injured neuron cell cultures and cause them to multiply. This scientific evidence prompted us to verify the effects in vivo.

Materials and methods

Following this scientific background, since year 2004 we treated chronic systemic tissue lesions such as spinal and brain traumatic injuries, in patients of both genders, aged 16 – 60 years old.

The whole project followed the rule of good clinical practice, established by European Community and published in the Italian “Gazzetta Ufficiale” (supplement N°191, 18/8/1997) N°39, 18/6/2001 and by the Helsinki Declaration.

Patients were selected on basis of inclusion-exclusion criteria and treatment interruption criteria (Fig 1). They were properly informed about the nature of the study, potential benefits and risks connected with it and were asked to give their informed consent prior to the start of laser treatment.

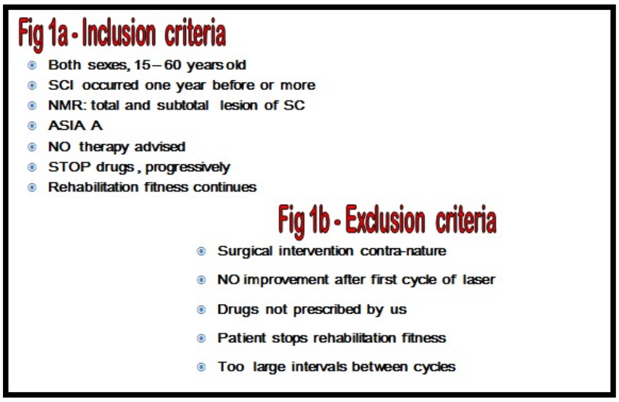


Fig. 1: inclusion and exclusion criteria

Patients admitted to the study were treated in our consulting room. Their documentation and treatment schedule were defined. Before treatment patients were informed about the steps that were followed. They were then submitted to the prescribed treatment according to the established protocol. Operator were attentive to any possible adverse immediate reaction. After treatment the operator checked health condition of the patients and keep them under observation for two hours after which they were released. Their comments were noted and the next appointment was fixed.

Both sides of the lesions and related domains of the injured apparatus were irradiated.

Laser treatment was done in consulting rooms, where instruments and drugs needed for the treatment of adverse radiation effects were placed. Each patient was treated in the same place for all the duration of the treatment.

Before starting treatment, patients undergo a check-up, with control of haemato-chemical parameters of blood and urines and function of principal organs, such as heart, liver, kidney, brain, lung, eye, endocrine system.

A qualified person controlled the efficiency of lasers and determined when laser was active. The same person was responsible for the application of safety rules following the standards of the American National Standard Institute (ANSI).

A third person evaluated rehabilitation results, measured with the same devices and the same criteria for each patient. An epidemiologist evaluated results and their statistical significance, comparing data obtained for the trials.

Energy doses may vary during the course of treatment on the basis of results obtained from time to time in each patient for each lesion. Duration of each session was 30 minutes in average.

No sensation was felt during diode laser irradiation, except a slight feeling of wind or heat.

The sample of the population obtained during period examined was significant for sex and age. All treatment groups were balanced with respect to baseline demographics and previous therapies.

All statistics data were calculated with the use of EpiInfo (statistical analysis software).

Effects of laser irradiation is strictly dose-dependent, a rule that applies to all non-surgical laser.

Laser dosages planned for treatment were below the dosage necessary to cause local burns.

Patients was kept under surveillance in order to avoid potential adverse reactions.

Laser could cause minor local burns (first degree), easily treatable with appropriate medication (antiseptic and laser wound healing stimulation). Allergic reaction to laser could be orticaria syndrome, itching and erythema. All these effects are easily treatable with topic medication (antistaminic drugs).

Follow up was done each month until one year, then every six months.

We enrolled 216 patients of both genders and aged 14-60 years, with traumatic spinal cord and brain injuries, occurred since at least one year before laser treatment.

Our preliminary experience started in 2004.

Standardization of these patients is difficult because each patient is totally different in terms of lesion, loss of sensitivity and degree of inflammation/degeneration.

Since trauma, all patients treated had total or subtotal sensory and motor paralysis under lesion level, clinically classified with ASIA (American Spinal Injuries Association) impairment scale, ASCII scale, EEG (electroencephalogram), NMR (Nuclear Magnetic Resonance), EMG (Electromyography), EPSS (Evoked Somato-Sensory Potentials), ESSP (Evoked Somato-Sensory Potentials) and neuro-physiological tests on spinal cord and brain lesions.

ASIA impairment scale classifies spinal cord injuries in 5 categories, depending on the degree of sensory and motor loss of function, sphincters included.

Further evaluations were done using ISCOS datasets. (www.iscos.org.uk/page.php?content=20 accessed 19 February 2012).

A diode laser 808 nm was used, with fluence 4-12 Joule/cm^2 in average, with a first cycle of 20 sessions, 4 per day. We repeated half cycle per month, for approximately 12 months. We do not know precisely how many cycles do these patients need and what is the end point of their improvement. These aspects will be object of further studies.

Laser which were used on lesions for anti-inflammatory and anti-edema purposes, were an 808 nm laser (Eufoton), 30 W PW, 3 Hz, spot size 5cm, fluence 720 J/cm^2 in total, 12 J/cm^2 for anti-inflammatory goal (Tab. 1); a 10600 nm, 15 W CW laser (General Project), spot size 10 cm, time exposure 20 sec for spot, as a skeletal muscle anti-spasm, not only on the lesion, but also along the nerves in the paralyzed area ; from December 2012, Nd-YAG laser 1064 nm (Aerolase Light-pode Neo), 5 W PW, 1 Hz, pulse duration 0,35 millisec, spot-size 6 mm, fluence 35 J/cm^2 for passage.

Tab 1 - Laser used

	Treatment of Inflammation and Edema	Support of Nerve Regeneration	Muscle Tone	Anti-Inflammatory Muscle Tone
Laser	2 diode 808 nm wavelength	4 diode 808 nm wavelength	CO_2 10,600 nm wavelength	Nd-YAG 1064 nm wavelength
Output power	10 W	10 W	15 W	5 W
Spot size	5 cm	5 cm	10 cm	6 mm
Fluence	12 J/cm²	4 J/cm2	36 J/cm²	35 J/cm²/passage
Total Energy	720 J	240 J		
Wave Form	1000 HZ	10 HZ	Continuous Wave	1 HZ
Tissue Target	Spinal Column	Nerve Trigger points Coherence Domains	Spinal Column area of the lesion	Area of Lesion and adjacent tissue
Sessions per day	4	4	4	3 passages
Sessions per First Cycle	20	20	20	20

Tab 1: parameters of used lasers

First cycle of treatment was composed of 20 sessions, 4 sessions per day, each session of 30 minutes, with minimum interval of two hours between the sessions.

It was possible to computerize laser emissions, and to use more than one laser simultaneously, saving time and discomfort for the patient.

Further monthly cycles were done, with different dosage (Fig. 2). This procedure could add anti-inflammatory with regenerative effects on nervous cells and/or on nerve functions.

All patients came to us with written opinions from orthopedists, physiatrists, neurologists and neurosurgeons, who defined lesions as complete and incurable and advised against any type of treatment and/or physiotherapy.

In fact we continued monthly laser therapy only if we noticed some positive and objective results after the first cycle of treatment. Other causes of interruption of treatments are shown in Fig. 3. Results obtained on patients who underwent laser therapy were evaluated by physiatrists other than the operator, and after first cycle they didn't known if the patients has had laser treatments.

Concerning sensory-motor clinical examination we used standard classifications, such as ASCII, ASIA, Asworth Scales and Franklin modified.

Before and after treatment all patients undergone NMR examination and some also had EMG and ESSP.

Fig 2 - Further monthly cycles

- 4 Diode laser 808 nm, same previous dosage
- CO_2 laser 10600 nm, same previous dosage
- Nd-YAG 1064 nm, same previous dosage
- Energy density variable
- Target Column, trigger points, coherence domains
- Four sessions a day
- Cycle of 8 sessions

Fig. 2: parameters of laser used in further monthly cycles

FIG 3 - INTERRUPTION OF LASER TREATMENT
49 Patients on 209 treated in total

No Results after 1st cycle	4 patients
Less And Slow Results	18 patients
Uncorrect Rithme of the Cycles	15 patients
Expensive therapy	9
Temporary results	3 patients

Fig. 3: causes of interruption of treatment

Results and discussion

Results are shown in Fig. 4 and Graph. 1.

In patients with spinal lesions at different levels, there was always a recovery in heat and tactile sensitivity as well as pain- and proprio-receptivity below the lesion, although in different extents and at different times, but it was always permanent and never transient.

Normal body thermic regulation was always recovered, if interrupted by the lesion, as normal anal sphincter control and sexual activity in both sexes, including erectile, sensory and ejaculatory functions. Bladder control was restored in women, but never in men in whom there was increased diuresis and urine loss during treatment, which may be due to a redistribution of bladder tone.

Muscle relaxant drug treatments and regulatory of bladder tone were gradually interrupted in all patients because they became not necessary. Gradually, there was muscular relaxation in spastic paralyses and a reduction and disappearance of spastic contractures, which were slowly replaced by normal spontaneous contractions, hyper-reflexia, and also fasciculation, in patients whom were restored to almost normal motility.

In any case, all the necessary effective measures were available and ready in case of any possible minor local burn or micro-vessel dilatation.

Appropriate physiotherapy is recommended for voluntary motor functions. Physiotherapists noted that patients undergoing laser therapy have better reactions and strength when doing their exercises and better muscle tone, which never develops into spasms. These results are transient at the outset during the early treatment cycles, lasting for about one month and then become permanent. This is may be dued to an accumulation of radiation or the possibility that patients are better able to do motor exercises or both.

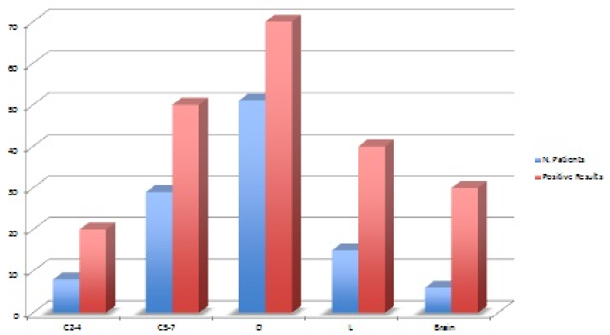
Results were monitored as usual, by Neurologists and Physical Therapists.

FIG 4- EVALUATION OF RESULTS UNTIL TODAY on 160 patients

- SENSORY SENSIBILITY — min increasing 2 metamers under the lesion
- UNVOLUNTARY MOTOR — improvement of muscle tone, posture
- VOLUNTARY MOTOR — variable, strictly connected with fitness
- ANAL SPHINCTER — improvement until normalization
- URETRAL SPHYNCTER — NO for men, normalization in women
- SEXUAL ACTIVITY — quite normal in 99 % of patients
- STAND UP — 135 p, in average after 100 irradiations
- WALKING — 15 p , in average after 120 irradiations
- ASIA & other classifications — change of minimum 1 class
- NMR — oedema and phlogosis signs diseappear, lesion of medulla reduced
- EEG, sEMG Biofeedback — significant improvement

Fig. 4: evaluation of result on 160 patients treated until today

GRAPH 1- Results on 160 patients



Graph. 1: results on 160 patients

Conclusions

Results obtained demonstrated that lesions still untreatable or inadequately treatable could be improved or totally recovered. The worldwide impact of the study is enormous.

Medical low-density laser stimulation for nervous tissue regeneration has received international and national attention and has been widely applied in the last thirty years. The present research is only a continuation of a long line of experimentation in this field.

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