Chapter 41

Laser treatment of central nervous system injuries: an update and prospects

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41.1 Introduction

Laser treatments of the central and peripheral nervous systems date from the late 1960s. One of the earliest articles by Fork (1971) in *Science* on argon laser treatment of nerves, came shortly after Mester et al. (1968) published their work on tissue stimulation with ruby and other wavelength lasers.

Then, Walker (1983) treated amputation neuromas of the lower limbs with ruby laser, and over the years, many other authors have dealt with the topic. There are many cited references in the *Proceedings of the International Congress of Laser Medicine* which is held in Florence and is now in its 30th edition. The *Proceedings of Laser Florence* 1999, 2000, 2001, 2002, 2003, and 2004, were published by SPIE (Longo et al., 1999); *Laser Florence* 2007 by Linux, Prague; *Laser Florence* 2008, 2009, 2010, 2011, and 2012 by the American Institute of Physics (Longo, 2008–2012); *Laser Florence* 2013 and 2015 by Medimond, Bologna (Longo, 2012-2013-2015); and *Laser Florence* 2017, once again by SPIE (Longo, 2017).

There are many other collections of bibliographies on the subject (Rochkind, 2008, 2009a,b; Longo, 2010; Hamblin et al., 2017), as well as approximately 100 other articles concerning laser treatment of the central nervous system (CNS) in international journals. My first book (Longo, 1986), and especially my latest *Laser Manual of Medical Technology*, describe laser's mechanisms of action in the diagnosis, treatment and surgery of all human tissues (Longo, 2015) (Fig. 41.1)

We began using this type of treatment at the end of 2003, selecting our patients on the basis of the inclusion/exclusion criteria listed in Table 41.1 (Longo, 2010). In the beginning the only patients who came to us had spinal cord damage with complete lesions, ranging from 6 months to many years, with complete lack of motor and sensory function classified AIS A, without any hope for improvement, and they brought medical reports written by eminent physicians who recommended against any type of treatment because they considered it useless.

However, things turned out differently, and we also began treating patients with incomplete spinal cord lesions, classified as AIS B, that is those who still had some sensation below the level of the lesion.

In all of our patients we gradually try to eliminate all their pharmacological medications on the basis of the results obtained—or which can be obtained—with laser treatment and associated physiotherapy. The patients always continued with personalized program of physiotherapy which is not the conservative type that is generally prescribed by the protocols of spinal units and centers of rehabilitation.

As to the exclusions, we do not even start treating patients who had undergone inadvisable surgeries such as muscle transposition, or had ruptured and/or strained tendons since these lesions cannot be remedied with regenerative laser treatment.

If there is no measurable and objective improvement after the first cycle of laser treatment we immediately interrupt the treatment. We also interrupt the treatment if the patient uses drugs, especially cocaine or excessive amounts of cannabis. We also stop treatment if the patient continues using nonprescribed drugs or if he or she does not comply with the recommended treatment intervals, or stops physiotherapy, or does not follow the prescribed program.

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R. Fork, 1971
J. Walker, 1981
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Many Others 1972–2017

FIGURE 41.1 References on the effects of nonsurgical laser therapy on central nervous tissue.

TABLE 41.1 Selection criteria of patients with traumatic spinal cord injuries.

Inclusion	Exclusion
• Both sexes, 15–60 years old • Lesion occurred 1 year or longer ago • NMR or CT: total and subtotal lesion of CNS • AIS A and B • No therapy possible • Stop drugs, progressively • Continue obligatory physical therapy	• Inadvisable surgery • No improvement after first cycle of laser treatment • Use of drugs not prescribed • Interruption of physical therapy

Source: *Longo, L., 2010. Nonsurgical laser and light in the treatment of chronic diseases. Laser Phys. Lett. 7(11), 771–786.*

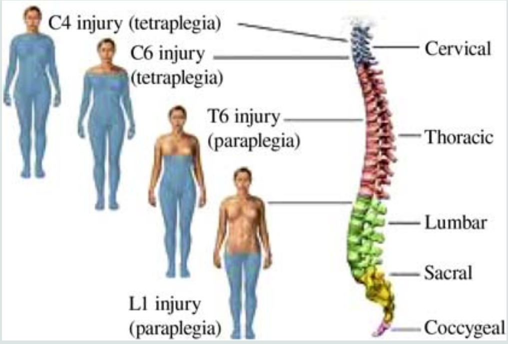
41.2 Clinical experience

From 2004 to 2016, we treated a total of 301 patients with traumatic lesions of the CNS (Table 41.2). Seventy-two dropped out for various reasons before completing the entire course of treatment, 10 had traumatic cerebral lesions. Therefore, our observations on posttrauma spinal lesions are based on 219 subjects.

Table 41.3 shows the different types of lasers we used. The numbers stand for the mean dose necessary for each patient. We always begin with this standard dosage and then gradually adjust it according to the results obtained.

We try to use at least three types of lasers (Longo, 2010; Longo et al., 1997; Yonezu and Kogure, 2013; Orchardson et al., 1997; McCaughey et al., 2010; Paula et al., 2014), of varying wavelengths: 800 nm diode, CO_2 10,600 nm and Nd:YAG 1064 nm, each in different doses to try to obtain different effects: antiinflammatory (Longo, 2010; Hamblin et al., 2017), antiedema, nerve regeneration (McCaughey et al., 2010; Paula et al., 2014; Wu et al., 2009; Yoshimi, 2007), and functional recovery.

TABLE 41.2 Patients treated from year 2004 until 2016.



301 in total

72 Patients stopped the treatment

10 Patients had posttraumatic Injuries of the Brain—BI

219 had posttraumatic Injuries of the Spine Cord—SCI

Source: *www.longolaser.it*.

TABLE 41.3 Laser therapy of the SCI—parameters.

	Antiinflammation and edema reabsorption	Nervous regeneration	Muscle tone regulation	Antiinflammation and peripheral regulation of muscle tone
Laser	Diode 808, 915 nm wavelength	Diode 808, 915 nm wavelength	CO_2 10,600 nm wavelength	Nd:YAG, diode 1064 nm wavelength
Output power (W)	10	10	15	5
Spot size	5 cm	5 cm	10 cm	6 mm
Fluence	12 J/cm^2	4 J/cm^2	36 J/cm^2	35 J/cm^2/passage
Total energy	720 J	240 J	Variable	Variable
Wave form	1000 Hz	10 Hz	Continuous wave	1 Hz
Tissue target	Lesion	Nerve trigger points and coherence domains	Around the lesion	Lesion's area and muscle-tendon joints
Sessions a day	4	4	4	4
Sessions a cycle	At first 3 cycles, 20 irradiations each, with interval of 1 month Further cycles, 8–12 irradiations each, in average with interval of 1 month			

Source: *Longo, L., 2010. Nonsurgical laser and light in the treatment of chronic diseases. Laser Phys. Lett. 7(11), 771–786; Longo, L., Giubilo, F., Romanelli, C., Longo, D., 2017. PT laser and physical therapy applied to traumatic central nervous system injuries: update. In: Hamblin, M., et al. (Eds.), Handbook of Low Level Laser Therapy. Pan Stanford Publisher, Singapore.*

Muscle tone can be affected in both modes (Yoshimi, 2007; Asagai et al., 2005; Ushigome et al., 2008; Ohkuni et al., 2008), that is, we can trigger hypertonia, contractions and spasms as well as hypotonia and flaccidity simply by modifying the dose.

The laser is the only known instrument among the many existing physical treatments that can have an opposite effect on the same tissue and same function by changing the dose. Schawlow said that the laser is the only instrument that can light a cigarette and put it out (Goldman, 1982).

In these patients it is very important to establish a diagnosis and then follow them up over time to monitor the outcome of the treatment (Table 41.4). However, there are some factors that must always be kept in mind. First of all, there are no two identical cases: the lesions, loss of muscle tone and function, and response to the treatments all vary from patient to patient. In other words, morphologically and topographically similar lesions of the CNS always involve a different loss of function and always respond to treatment differently.

Another important point is that there is often a dissociation between the anatomical and functional aspects of the lesion. Furthermore, the lesions are never completely measurable, reproducible, or repeatable. Since the patients and the lesions do not respect basic mathematical criteria, and given all the variables, statistical analyses are not applicable.

And yet, all over the world, statistical analyses are applied to these lesions just the same. It is on the basis of those analyses that diagnostic and treatment protocols are established, and decisions made as to whether the patient is treatable or untreatable—that is, whether he has any hope of functional and anatomical recovery. Unfortunately the patient is frequently given the verdict: “Dear Sir (or Madam), you are in a wheelchair and will remain in it for the rest of your life” or, “No, don’t worry, you will walk again.” It would be wiser not to issue these verdicts, be they positive or negative because of all the reasons listed above. It is the protocol that must be adapted to the patient, and not the patient to the protocol: This technical error is made all over the world and almost always in Italy, with the result of often giving a wrong prognosis and incorrect treatment causing enormous psychological and physical harm (Table 41.4).

To assess treatment we have the physiatrist’s clinical neurological and instrumental examinations (Table 41.5).

On the clinical level we follow more or less standardized international scales for assessing sensory and motor sensitivity below the lesion level such as the American Spinal Injuries Association (ASIA), the Asworth for muscle tone, the Franklin scale for motor function, and many other scales for each function.

However, the patient must always be the focus of the assessment. Therefore we must take into account what he and all the people around him have to say (Table 41.6).

Among the instrumental examinations, diagnostic imaging gives us an enormous amount of information, as does complete muscular assessment from the simple electromyogram to surface electromyography, to somato-motor and

TABLE 41.4 **Diagnosis and therapy of CNS traumatic lesions.**

- Similar CNS lesions always give different function loss and different answer to the therapy
- Anatomy and function often are dissociated
- Lesion is never totally measurable, reproducible, repeatable
- *Statistical criteria: Not valid, because there are many variable factors*
- *Protocols*
- Always relative, never absolute!!

TABLE 41.5 **Treatment evaluation.**

- *Specialistic clinic evaluation*: AIS score, Modified Ashworth Scale, Franklin Scale, others
- *Auto-evaluation* of the patient and his family
- NMR, CT
- EMG, sEMG
- ESSP, ESMP (somato-sensor and motor evoked potentials)
- HHD (hand-held dynamometers)

TABLE 41.6 Specialistic clinical evaluation.

AIS score, Ashworth Scale modified, Franklin, others
• *Nontotally objective* • Not totally measurable • Easy reproducibility • Repeatable

TABLE 41.7 NMR, CT, Rx.

• Objective • Lesion not totally measurable ("blind" solid angle of about 25 degree) • Reproducible • Repeatable • Often *dissociation* between anatomical and clinical signs

somatosensory evoked potentials as well as dynamometry, that is the measurement of muscle strength. However, each of these diagnostic tools has its limits. Specialized clinical examinations are never completely objective because any international assessment scale is subject to a certain degree of subjectivity both on the part of the patient and the examining physician.

Diagnostic imaging is clearly a more objective method, but it has the drawback of a blind spot of about 25–30 degrees in which we see absolutely nothing. Therefore the diagnosis of a complete or incomplete lesion is merely presumed and not absolute. Although imaging techniques offer good reproducibility and repeatability there is often poor correlation between anatomical and clinical signs (Table 41.7).

For example, one patient had a T11-L1 lesion with dislocation of the stumps, rupture of the thoracic aorta and, without a doubt, a complete lesion (already in 2004) with a series of statements from the Italian, Austrian, Swiss, and North American “Gotha” of neurosurgery, neurology, and physiatry who recommended against any type of treatment. We treated him in 2006, he stood up in 2007, has been walking with braces since the end of 2007, and from ASIA A he is now ASIA D. Each year the patient had a CAT at the lesion level and the lesion was always evident and unchanged except for the total absence of edema and signs of phlogosis, which had disappeared after about 60 applications. The lesion remained unchanged until 2011, when, at last a column of tissue appeared which suggested that the lesion had begun to experience healing. Therefore there was an evident dissociation between the clinical signs, which clearly began improving since 2007, and the anatomical imaging signs which only improved in 2011 (Figs. 41.2–41.3).

Muscle assessment is objective, repeatable, and reproducible, but it is subject to certain variables that may include errors in posture and errors in selecting the measuring points, the condition of the skin surface and other morphological and logistical factors (Table 41.8).

For example, Fig. 41.4 shows a 43-year-old male with a complete T4 lesion. After a cycle of laser treatment, the left side began showing a response to surface electromyography, and with 70 treatments his right side also began normalizing.

Tables 41.9–41.11 summarize the patients treated according to the topography of the lesions: the patients who interrupted treatment are shown in yellow. There were 7 patients out of 219 who remained unchanged. However, several patients interrupted the treatment, not for lack of results, but for the slowness of seeing results; they may have had expectations that were too high having been poorly advised, or they may have had “poor behavior” that is, not following the schedules we give them, and sometimes also because of the costs. We had a total of three relapses: one due to an excess of physiotherapy and one for having totally cut-out the physiotherapy. In two cases, albeit through opposite causes, an edema probably reformed on the site of the lesion and began compressing the perilesional tissue and interrupting any connection between the two damaged stumps. A third patient relapsed because a fall from the wheelchair caused another traumatic injury on the site of the original lesion.

Table 41.12 summarizes the results obtained.

FIGURE 41.2 Patient—31-year-old male, complete lesion T11-L1, ASIA A, from the year 2004. Laser therapy started in June 2006, he started to walk with tutors and walking aids from the end of the year 2007, after 134 irradiations, ASIA D. *www.longolaser.it.*

Examining the patient before and after each laser treatment cycle, we consider the results positive if, after 20 applications, superficial and/or deep tactile, and/or pain, and/or heat and/or pressure sensitivity falls, at least two dermatomes below the lesion. Smooth muscle must show at least 1 degree of improvement per cycle, while voluntary muscle responses depend on the quality and amount of physiotherapy during and in the intervals between cycles. Anal sphincter control and everything related to bowel function and reflexology normalized in 90% of the patients, on the average after 120 applications. In the past 5 years, 52 out of 56 patients with complete lesions had normal rectal exploration and bowel function. We read everywhere that in patients with complete lesions, these functions cannot be restored once they have been lost. Perhaps it is time to correct the old books. Bladder/urethral sphincter control was almost completely restored in the women, but never in the men.

Nearly all the patients, both men and women, resumed sexual activity including erectile, ejaculatory, and sensory function, in fact some of the patients have produced children.

One hundred sixty-one patients recovered sufficiently to be able to stand after an average of 120 applications and 42 patients can walk with braces.

We carry out clinical assessments on the average of once every 6 months; instrumental tests every 2 months for neuromuscular function and X-ray assessments every year. In cases of traumatic cerebral lesions, electroencephalograms and psychological evaluations are done every 3 months.

The cause/effect relationship between applied laser treatment and results obtained cannot be scientifically controlled or proven since we cannot conduct proper double-blind or single-blind controls on homogeneous groups analyzing one variable at a time. However, we can make some scientific observations (Tables 41.13–41.14).

For example, due to personal reasons, 39 patients interrupted laser treatment for more than 2 years. When they returned their conditions were unchanged with the same level of sensitivity below the lesion as when they had they left. The condition was not the same as at the start of treatment, but as at the end, which means that they all maintained the positive results they had obtained, without however, gaining further improvement. Resuming laser treatment after an interval of years, the patients began to improve again with further positive results. If these improvements were not due to the laser treatment (rather than being spontaneous recovery), how come the patients did not continue to improve

FIGURE 41.3 October 2011: column of new nervous tissue can partially repair the lesion. *www.longolaser.it*.

TABLE 41.8 sEMG, EMG, ESSP, ESMP, HHD.

– Objective
– Reproducible
– Repeatable
- Artefacts caused from different condition of the skin and of different sites of measuring
- Only on/off activity
- Discomfort for the patient (needles)

during the period that they had suspended the laser treatments? And, how come they began to improve again after they resumed the treatments?

There are practically no adverse reactions except for the potential danger of a first degree burn measuring a few centimeters (Table 41.15). Another potential effect is a photobiomodulation overdose which can cause opposite, albeit, transient effects: inflammation and anaesthetization, instead of reducing the local inflammation and facilitating functional recovery below the lesion. We have never seen this, but theoretically it could happen if the lasers are used by nonexpert physicians or physiotherapists (Longo, 2010). Complications: for the patient(s) none, for the physician, many.

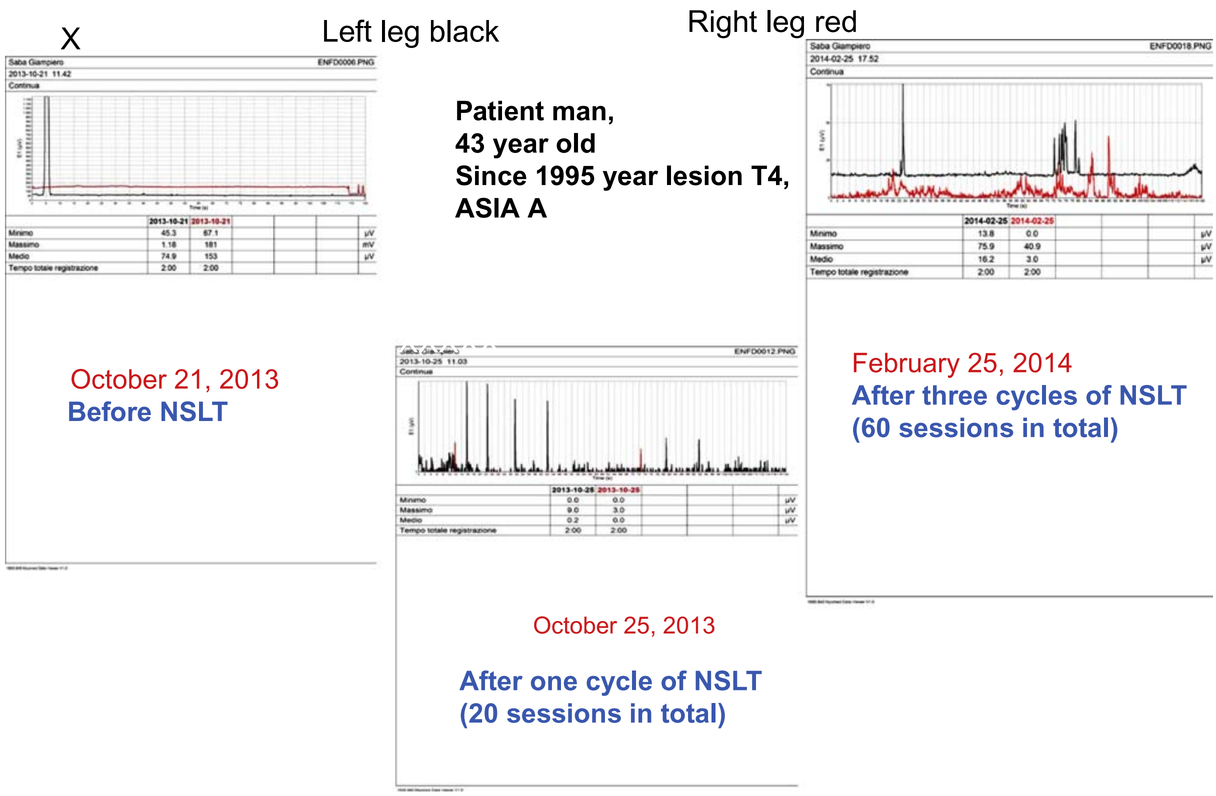
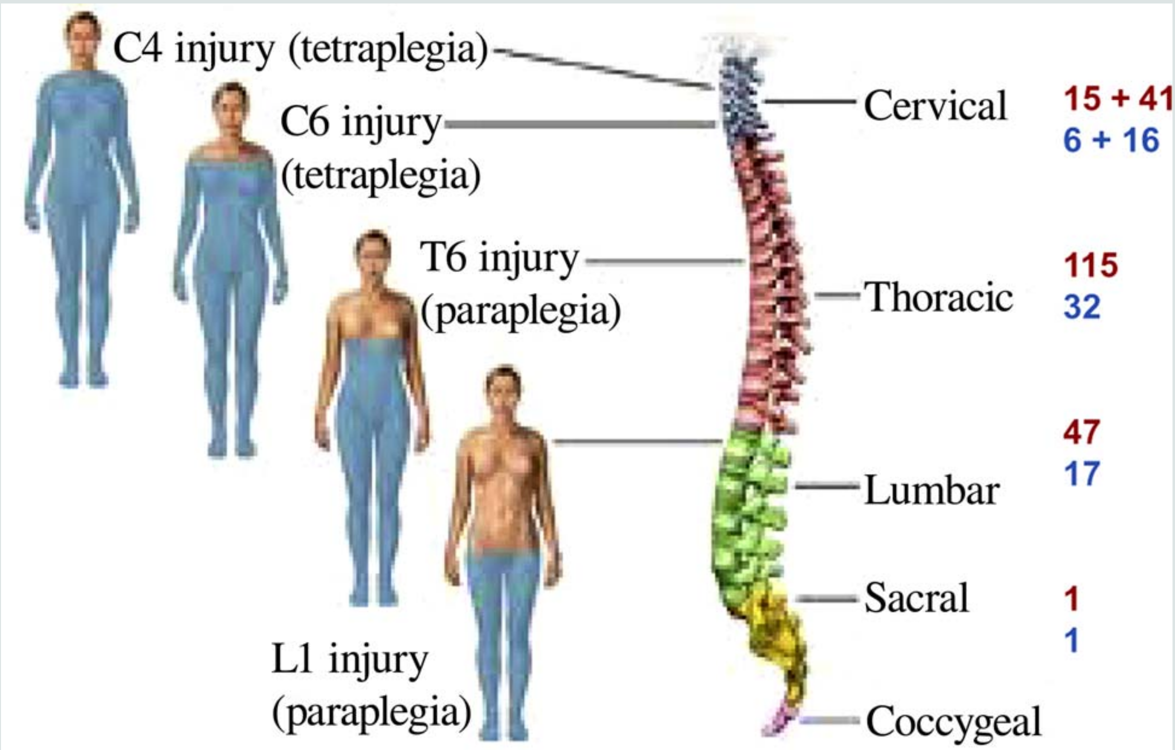


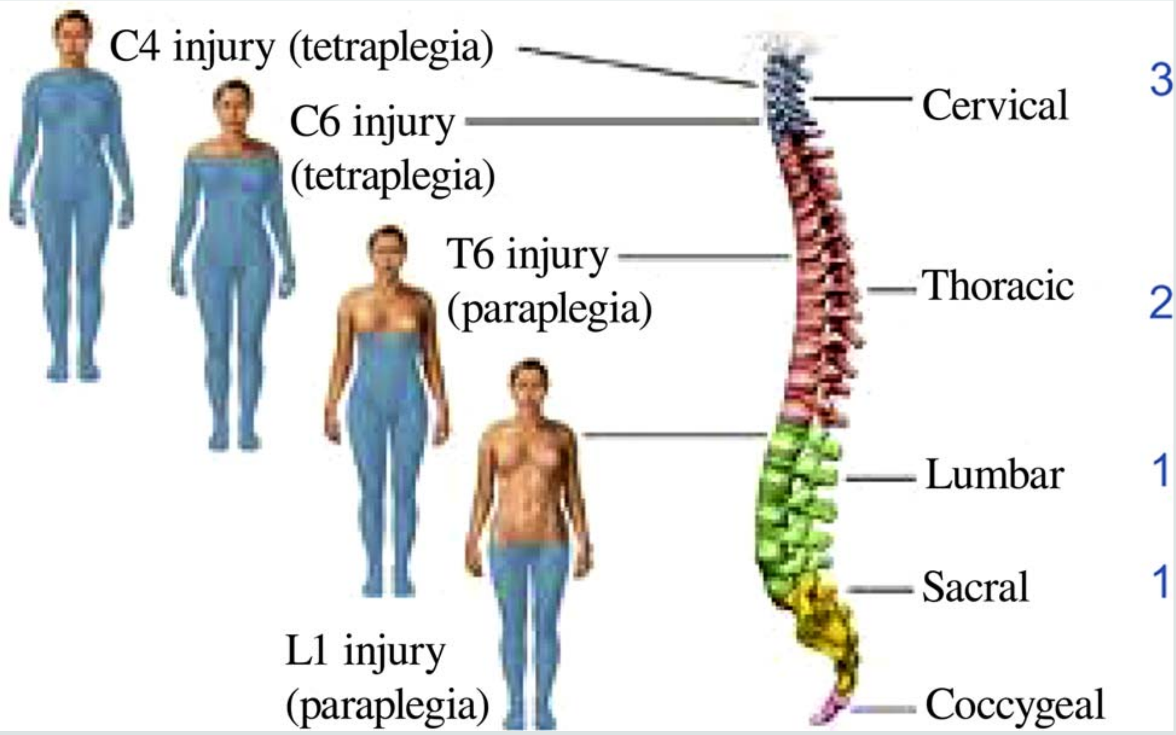
FIGURE 41.4 sEMG of quadriceps muscle.

TABLE 41.9 Patients treated from year 2004 until 2016 in blue: patients which interrupted the therapy.



Source: *www.longolaser.it*.

TABLE 41.10 **Patients without result after 20 sessions.**



Source: *www.longolaser.it*.

TABLE 41.11 **Interruption of laser treatment 72 patients on 301 treated in total.**

No results after first cycle	7 patients
Less and slow results	28
Incorrect rhythm of the cycles	13
Expensive therapy	21
Temporary results	3

For example, after about 100 applications per patient normalizing muscle tone, we managed to have six muscle relaxant pumps removed, this means a considerable loss for the pharmaceutical industry because the pumps are included in the protocols of nearly every spinal unit and are proposed immediately after a lesion occurs, especially in young patients subject to acute spastic syndromes immediately following an injury. These pumps cost €5–6, inserting them the same, and there is the cost of the drug that must be administered for the rest of the patient's life; in addition he or she will likely be psychologically impaired as well. With laser treatment, as muscle tone and sensory function are recovered, the pumps can be removed, and, except for a few cases, it may even be better not to insert them at all. And then there is jealousy among colleagues, which unfortunately exists in every professional field, not just in medicine.

TABLE 41.12 Evaluation of the results until today on 301 CNSI patients.

Sensation Min returned to two metamere levels below the lesion	
• Involuntary motor	• Improvement in muscle tone, posture, MIN 1 degree per cycle
• Voluntary motor	• Variable, strictly connected with fitness degree
• Anal sphincter	• Improvement 90% until normalization, ~120 irradiations
• Urethral sphincter	• *No* for men, normalization in women, ~120 irradiations
• Sexual activity	• Quite normal in 99 % of patients, ~100 irradiations
• Stand up	• *171 p*, after an average of 100 irradiations
• Walking(ASIA C−D)	• *42 p*, after an average of 120 irradiations
• ASIA and other classifications	• Minimal improvement by *1 degree/6 months*
• NMR, CT	• Edema and inflammation disappear, lesion of medulla reduced after 60 irradiation approximately
• SSEP, SMEP, sEMG, HHD	• Improvement of MIN 2 muscles each two cycles
• EEG	• Progressive *improvement*

TABLE 41.13 Questions.

- The improvement of these patients could be spontaneous or caused by other therapies, such as physical therapy alone.
- Cause/effect ratio between laser and results is not controlled and not scientifically demonstrated.
- Follow-up?
- Side effects and complications?

TABLE 41.14 Answers.

- Thirty-nine patients stopped laser treatment for 2 years and more, for personal reasons.
- When they come back to continue NSLT, the situation of these patients was the same as the moment they stopped the treatment: follow-up was positive, as always.
- Once they restarted the therapy, the improvement restarted a second time.

TABLE 41.15 Side effects and complications.

- *Side effect*—Skin burn first degree, exceptional
- *Complications*: not for patient
- *Only* for physician: stop myorelaxant and other drugs, Jealousy of colleagues and more...!

41.3 Mechanisms of action

There are many hypothesis on the mechanisms of action (Table 41.16):

- There is an important antiinflammatory and antiedema effect (Longo, 2010).
- There is stimulation of neural stem cell regeneration, because lasers can make the neural stem cells multiply, regenerate, differentiate, and migrate (Anders et al., 2005, 2008).
- There is direct stimulation of neuron function, and in cultures there have been transformations of glial cells into functional neurons capable of transmitting nervous electric stimuli, a transformation made possible by 36 genetic mutations (Anders, 2009; Oron et al., 2007).

TABLE 41.16 **Hypothesis of mechanism of action.**

1.	Active hyperemic, antiinflammatory, antiedema effects
2.	Stimulation of nerve and progenitor cells regeneration[a]: *new tissue welding or bypass*
3.	Stimulation of neuron function: transformation of the neurons from glial cells to functional cells, between 36 genic mutations
4.	Influence on the bioplasma: energy around the body from 300 until 2000 nm (Inyushin and Chekurov, 1975)
5.	Influence human energy field (Brennan et al., 1987)
6.	All mechanisms listed below

[a]*Copyright 2006 by Anders, J., Longo, L., Waynant, R., Ilev, I., Romanczyk, T. USHUS Bethesda, FDA, USA; ILM Firenze, Italy.*

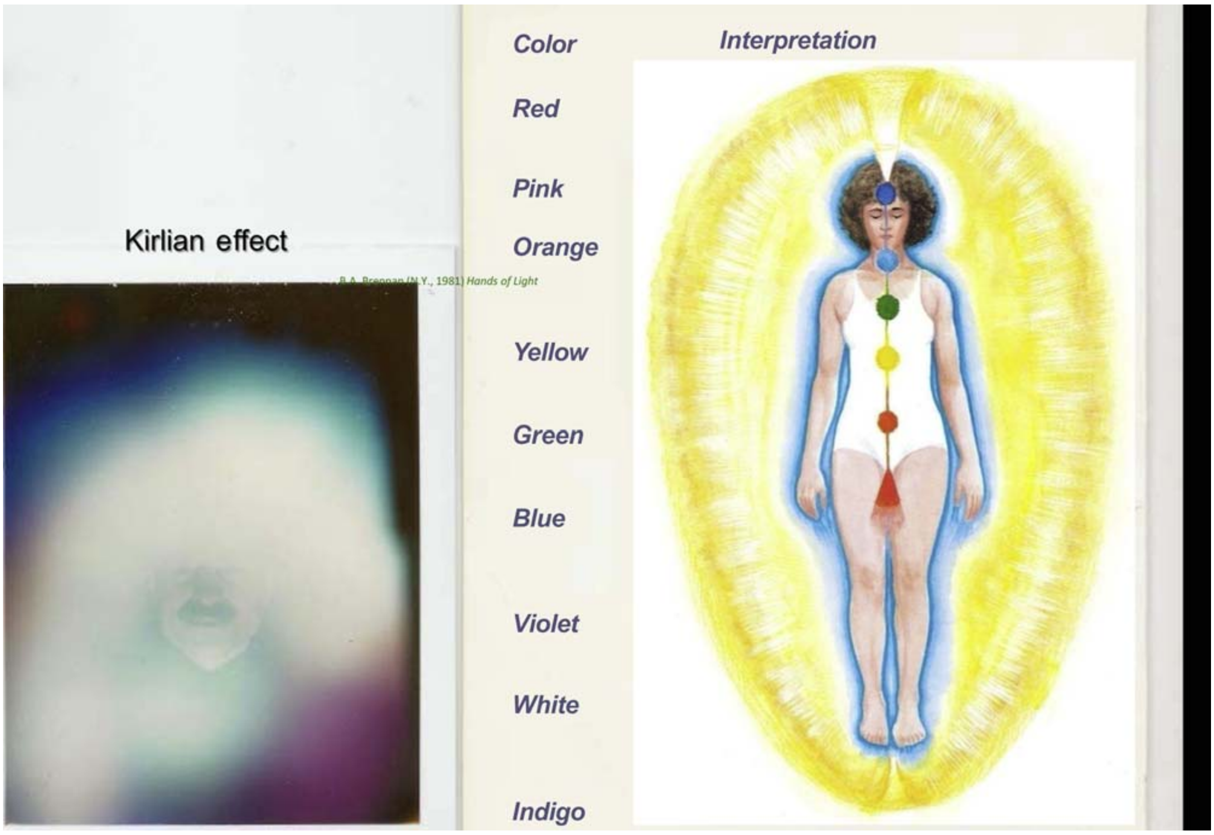


FIGURE 41.5 Body energy anatomy.

Then, there is the influence on the cell metabolism. We know that we produce energy that we exchange with the environment continuously, and these energies are harmoniously distributed throughout the body and around it, in a sort of cap that surrounds the body and is called bioplasma. Russian scientists have identified and measured that light ranges from 200 to 2000 nm (Inyushin and Chekurov, 1975). Lasers are light and probably fit into this mechanism as well.

All of these mechanisms can interact with each other. Fig. 41.5 shows the anatomical energy of the human body (Brennan, 1987), on the left is my energy anatomy in 1996, it will be very different now, it was measured in Orlando (Florida), and this is the energetic anatomy of a flower (Clarke) (Fig. 41.6). All living beings have an energetic anatomy. And the energy/matter interaction is indispensable for life.

In conclusion (Table 41.17), on the basis of our findings, we can say that by using different wavelengths at the same time, nonsurgical laser treatment of traumatic spinal lesions gives positive objective results. These results can be measured with different clinical and instrumental methods which are synergic but the values are not absolute.

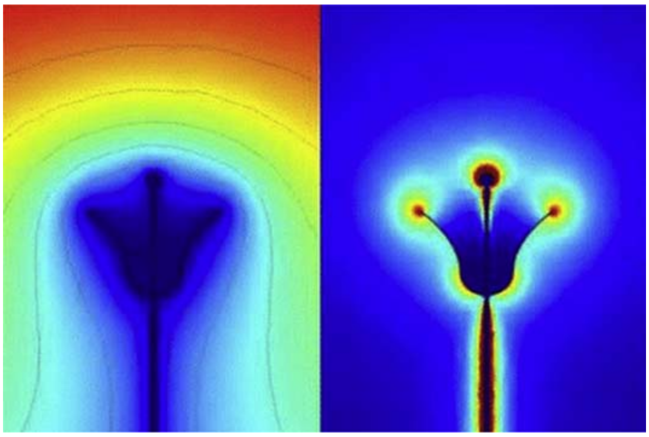


FIGURE 41.6 Electrical potential of flower J. Clarke et al., *Science* (2012). *www.longolaser.it.*

TABLE 41.17 Conclusion.

NSLT of traumatic central nervous system injuries gives positive results in the recovery of anal sphincter function and anal reflexes in both sexes, using all wavelengths simultaneously: 808 (915), 1064, 10,600 nm.
Regarding the urethral function, positive results are obtained only in women, not in men.
Multiwavelength lasers could have synergistic effect.

Unfortunately, the existing limits in assessing spinal lesions also apply to laser treatment, but evaluating the results achieved from several viewpoints we can conclude that this type of therapy associated with targeted and specifically designed physiotherapy for each individual should become routine in all patients with spinal cord injuries, adapting the protocol to the patient and not vice versa (Rochkind, 2009c; Longo, 2017).

41.4 Appendix—Motor control and the Grimaldi maneuver

D. Longo, G. Cherubini, V. Mangè, P. Lippi

The development of new or different forms of motor behavior should be one of the main goals of rehabilitation therapy. Exercise should generate new or different movements aimed at reaching the goals. Those goals are achieved by the available motor resources. In patients with strokes, or neurological or orthopedic diseases, the behavioral goal combines the available motor resources and completes the task with one or more combinations of potentially available motor units. The reduced availability caused by the pathologic event forces the motor system to use stereotyped patterns that have little flexibility and little redundancy, in other words, they are inadequate. The traumatic event can produce a drastic reduction in motor resources needed to achieve the goal: one example is the onset of spasticity in neurological diseases. Physiologically spasticity is defined as a motor disorder characterized by a velocity-dependent increase in the tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyperexcitability of the stretch reflexes as one component of the upper motor neuron (UMN) syndrome (Lance, 1980).

The therapeutic exercise that uses the principle of shortening and solicitation of stress intention can lead to a reduction in spasticity, the recovery of strength and coordination, and lastly, when possible, all perfectly coherent with the equilibrium point hypothesis and threshold control. The neural control of motor actions involves changes in parameters of the system. A well established form of parametric control—threshold control—is briefly reviewed with a major focus on how it helps to solve several motor problems, in particular, the problem of the relationship between posture and movement and redundancy problems in the control of multiple muscles and joints (Feldman, 2006).

It is widely known that the emergence of new and/or different behaviors can take place via two processes: facilitation and learning. Facilitation does not necessarily involve a stable modification of the motor components, since the removal of the facilitation generally leads the motor system back to the previous level of competency. Therefore, the only road to take is that of directing the process back to learning, in the sense of developing new and/or different behaviors. For the ecological school, the learning process is identified by the acquisition of an order of superior or different systemic complexities. In this case, the complex dynamic system is identified as the motor perception apparatus of living beings.

Learning, from this standpoint is an emerging phenomenon, since it is takes place as a spontaneous phenomenon. However, it can only occur in the presence of specific physical conditions (critical instability) that become evident with the onset of a new and/or different motor behavior which could not be expressed before. Emerging phenomena can only occur spontaneously in the presence of complex dynamic systems with many degrees of freedom. It has been shown that central control levels are able to change a component (λ) of the threshold length value, at which the activity of muscle is initiated. By shifting the thresholds of appropriate muscles, the nervous system produces movement or, if movement is blocked, isometric torques (Feldman, 2006).

The neuromuscular system behaves similarly to a mass-spring system; it is a specific type of oscillatory system. According to Latash, the group, or assembly of many oscillatory systems controls the dynamics of the attractors. The principle of motor abundance suggests that CNS facilitates solutions that are equally capable of completing the task. It does so by imposing restrictions on the body-environment systems and allowing the solution to emerge at a given real state of the system (which is never repeated in subsequent trials) (Latash Mark, 2012). The restrictions represent a guide for the dynamic processes so that the actions are not caused by restrictions, but rather some actions are excluded by them (Scott Kelso et al., 1980)

The actions are characterized by self-organization, lacking a controller and are stable, flexible, redundant, and competitive. In some ways they are similar to motor learning processes. Spinal mechanisms adjust independently with respect to variable contextual conditions (Grimaldi et al., 1986).

According to Gibson and Turvey's description, motor behavior is guided by information. Information understood ecologically is a special kind of resource—a resource about the nature and whereabouts of other resources understood as opportunities for action (i.e., affordances) that further biological processes (Turvey and Carello, 2011).

The information is direct and structured with respect to the isomorphic action/perception. In terms of direct perception, tissue deformations acquire informational characteristics: the stimuli that reach the receptor surfaces are unique and specific to the action, and have properties which traverse the different states of matter, that is, physical, physiological, and psychological states. In transformation processes, the properties remain unchanged (isomorphism). Perhaps in this way we can better understand the self-descriptive character of information in complex dynamic systems since the real properties (stimulation patterns) do not have to be compared with an internal model or with the representation in order to be able to describe reality.

We suggest that when it is applied to a motor system, Grimaldi's muscle shortening maneuver (MSM) produces instability in the information field, and informational catastrophe that leads to instability of the neuronal flow needed for perceptive and motor control. The instability of the information field can be mediated by any receptive organ (tactile, visual, proprioreceptive) when faced with such a disturbance or disruption the nervous system is physically forced to make and/or generate different relations, abandoning stereotyped behaviors, and releasing degrees of freedom. It is possible that during the instability there is a loss of isomorphism, which is restored with the change in the order of systemic complexity (learning). This process produces an informational catastrophe in the neuromuscular spindles forcing them to set new muscle thresholds. This kind of maneuver is an active but involuntary training for the patient (Longo et al., 2017).

The MSM produces a shortening of the target muscle when it should create tension in stretching. The energy absorbed by stretching, which should transform into electrical activity and, therefore, into muscle strength, can or should find a new channel that should lead to the evocation of new and/or different motor components, configuring a learning process. The emerging motion, as clinically manifested, consists of setting new thresholds, the respective characteristics remain unchanged, and is probably allowed by the activating latent synapses, or by significant changes in the sensitivity to stretching. The consequence may be the appearance of previously absent voluntary movements, with increases in the strength, range, and the speed of executing the movement. Clinical observations could also detect increased strength on repetition of the motion, the development of new trajectories often accompanied by a reduction of any muscle hypertonia in neurologically impaired patients or the development of motion due to the action of the antagonist muscle and/or other synergy. Reduced pain is a frequent result in orthopedic diseases treated with MSM exercise therapy. Some of the method's protocols offer a useful alternative or complementary resource to existing treatments. Once a coordinative structure is set up, it is redundant, stable, precisely flexible, and it maintains a behavior characteristic of some nonlinear oscillatory systems. The new coordinative structure can protect the system against disturbances (clearly within limits) and therefore provide a certain amount of stability to motor performance. The authors support processes of self-organization since "groups of neurons that share similar thresholds and similar range pairing together give rise to the neuronal firing" and are able to produce a coordinated pattern to achieve the motor goal. When the process is evoked for the first time after the lesion-causing event, it can lead to the appearance of new motor components which will complement the existing motor functions. The new motor component is automatically and immediately available. The features of the MSM maneuver can be summarized as follows: (1) segmentary and overall assessment of the functional system, to detect the principal motor dysfunction; (2) identification and preparation of the exercise setting (the exercise does not take long, an average of 15 minutes can be sufficient); (3) segmentary and overall assessment a few minutes after completion of the exercise, and an assessment a few days later.

Some manual maneuvers can be done with the patient in different positions. The most important variables of the exercise are the therapeutic range or range of joint excursion—which may vary—and the speed of execution. The absence of structured muscle-tendon retractions is essential for the range of motion required by the exercise.

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