

ELECTROTHERAPY FOR PHYSIOTHERAPISTS: principles and practice

**CIOBANU DORIANA IOANA
DRĂGAN ANCA MARIA**

2025



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Autori:

CIOBANU DORIANA IOANA

DRĂGAN ANCA MARIA

Director editură: GHEORGHE POP

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INTRODUCTION

The term "**Electrotherapy**" is used in a very broad sense, in the context where certain methods, such as ultrasound or laser therapy, for example, do not belong to the group of electrotherapeutic modalities, as long as they do not produce any form of electric current. Therefore, in recent years, the term "electrophysical agents" has been increasingly used, which encompasses a much broader spectrum. Both terms are used equally, but it is inevitable that at some point there will be a transition from the term electrotherapy to electrophysical agents. (Watson, 2010)

Electrotherapy is a constant component of the kinesiotherapy practice, and it has been considerably and continuously evolving. The most popular electrotherapeutic modalities used today are similar to those from 60 years ago and even further back, and are based on the same principles.

Modern electrotherapy practice must be evidence-based, and electrotherapeutic modalities must be used appropriately. When used where, when, and how it should be, electrotherapy can be extremely effective. If used incorrectly, it will either have no effect or worsen the situation – a truth that applies to any other therapy as well.

The practitioner's ability to use electrotherapy lies in their capacity to make appropriate clinical decisions, to choose the most effective therapeutic modality, to know when it should be applied, and, not least, to rely on practical evidence when making such decisions.

Basic Model in Physiotherapy Intervention

A simple but effective example of a decision-making model is presented in the diagram below. All electrotherapeutic modalities (except for biofeedback) involve the introduction of a certain amount of energy into a biological system. This energy causes one or more physiological changes with therapeutic benefits.

From a clinical perspective, it is likely more efficient to proceed as follows:

- ✓ determine the nature of the problem being addressed
- ✓ establish the physiological changes that must occur to achieve the desired effects
- ✓ identify the electrotherapeutic modality that will bring about the desired physiological changes then
- ✓ select the appropriate dose to achieve the desired effects
- ✓ apply the treatment

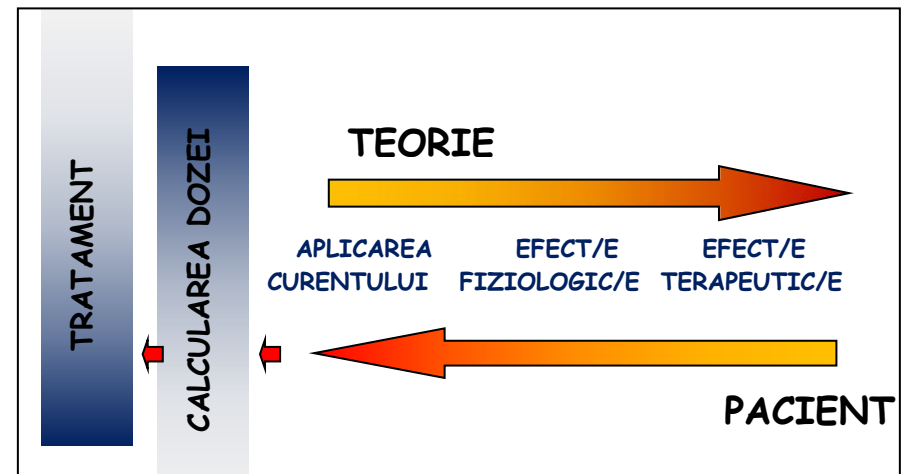


Fig. 1 Decision-making model¹

Dose selection is very important because the effects of the treatment are not only dependent on the electrotherapeutic modality used but also on the dose that is applied. If possible, practical evidence should also be considered, as there are studies that specify a therapy is not effective, but other studies demonstrate that the same therapy works at a different dose. (Watson, 2008; 2010)

¹ (sursa: Watson, 2012, *Key Concepts in Electrotherapy* <http://www.electrotherapy.org/modality/key-concepts-in-electrotherapy>)

The Bioelectric Body

The electrical activity of the body has been used for a long time both for diagnosis and for monitoring the effects of treatment, being closely correlated with the excitability of tissues. Examples include EKG, EMG, EEG. In more recent approaches, attention is directed towards tissues that do not have such a high degree of excitability but in which the presence of endogenous electrical activity has been demonstrated. The endogenous electrical activity of the body is demonstrated by multiple sources, some of which are well-documented, while others have obscure origins and mechanisms of production. The relationship between endogenous electrical activity, injury, and healing has been researched in various areas of clinical practice and is thoroughly documented in numerous publications (Watson 2002, 2008).

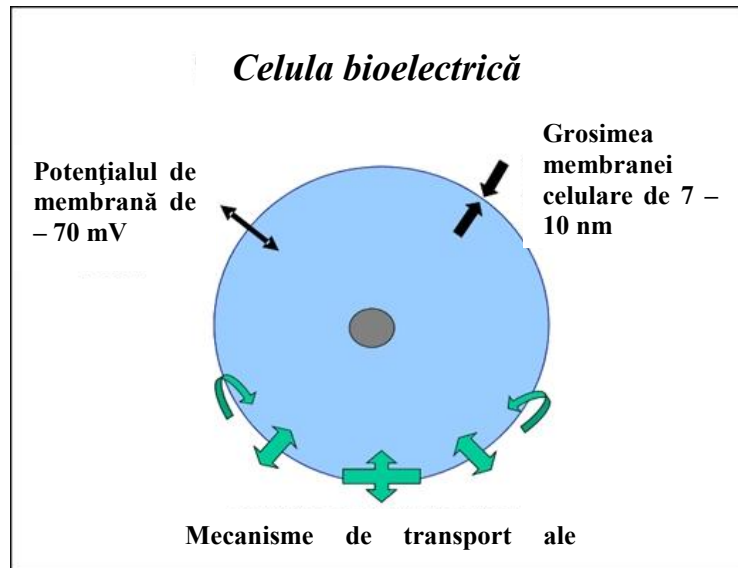


Fig. 2 Bioelectric cell ²

The Bioelectric Cell

Every living cell has a membrane potential (of approximately -70 mV), with the interior of the cell being negative in relation to the outer surface. The membrane potential of the cell is closely linked to membrane transport mechanisms, in which much of the material passing through the membranes is ionic (electrically charged particles), meaning that changes in the movement of charged particles will influence the membrane potential. Conversely, changes in the membrane potential will influence the movement of ions. In relation to the size of the cell, the membrane potential is massive. The membrane has an average thickness of 7-10 nm².¹

¹ a nanometer is a unit of length equal to one billionth of a meter.

² source: Watson, 2012, Key Concepts in Electrotherapy, <http://www.electrotherapy.org/modality/key-concepts-in-electrotherapy>

The voltage equivalent is somewhere around 10 million volts per meter (which is impressive). The energy in the cell membrane allows for the modification of the cell's behavior – one of the fundamental dogmas of electrotherapy – thus making the difference between the behavior of cells and tissues. Different cells and tissues respond preferentially to different types of energy and different doses.

Electrotherapy (electrophysical agents) has a well-established place in clinical practice. When used appropriately, electrotherapy proves its effectiveness. On the other hand, electrotherapy can also be applied ineffectively (as clearly demonstrated by practical evidence), and the practitioner must have the ability to rely on practical evidence to make the best decisions.

Brief History

- **1744-1745:** Johann Gottlob Krueger – concepts about electricity
- **1786:** Galvani – discovers that there is electricity in the human body
 - experiments with electrical stimulation of the gastrocnemius nerve
- **1796:** Volta – invents the galvanic cell
- **1827:** Stefano Marianini – electrically stimulates paralyzed muscles
- **19th century:**
 - Galvanic baths (Karlsbad)
 - Stanger baths (Ulm)
 - Neurophysiology research
- **1940:** Ginsberg, Milinowski – introduce pulsating high frequency
- **1949:** Gierlich – combined therapy with ultrasound and diadynamic currents
- **1968:** Hufschmidt – therapy for spastic musculature
- **1980:** – medium frequency interference currents

1990: – medical lasers for physiotherapy (LLLT)

– shockwave therapy

– magnetic stimulation¹

¹ Dragan Adriana (2007) *Curs de electroterapie*, pag. 1

1. PRINCIPLES OF ELECTRICITY IN ELECTROTHERAPY

1.1. Electricity. Conceptual Delimitations

ELECTRICITY s.f 1. One of the fundamental physical properties of matter, manifested through the set of phenomena related to the appearance, movement, and interaction of bodies carrying electric charge. The totality of electrical phenomena. (Source: DEX '98)

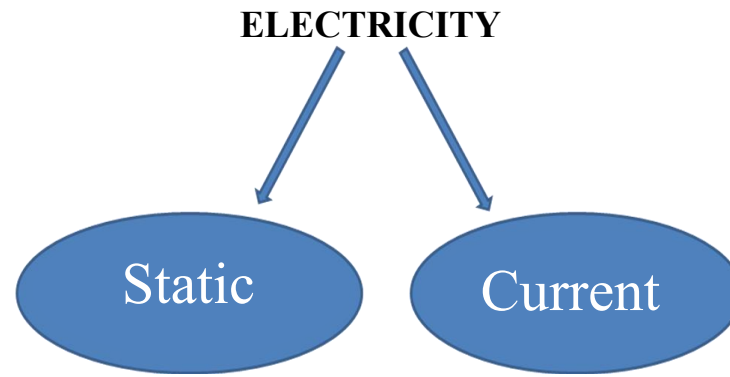
ELECTRICITY f.1. A form of energy produced by the movement and interaction of particles carrying electric charge. The totality of electrical phenomena. A branch of physics that deals with the study of electrical phenomena. [G.-D. of electricity; Sil. -lec-tri-] /<fr. *électricité*, lat. *electricitas*, ~atis (Source: NODEX)

ELECTRICITY s.f.1. A state property acquired by bodies after being rubbed against each other and then separated; electric charge. The totality of phenomena produced by the rest and movement of a particle called an electron. A branch of physics that studies electrical phenomena. [Cf. fr. *électricité* < lat. *electrum*, gr. *elektron* – yellow amber, where the phenomenon was first observed by Thales]¹

Electricity = *property of certain fundamental particles of matter that have a force field, manifested by the accumulation or absence of electrons on an atom or body*
= *A form of energy associated with the existence and interaction of electric charge, manifested by the accumulation or absence of electrons on an atom or body; and which present properties magnetic (electromagnetic), chemical, mechanical (electrokinetic) and thermic*
= *A form of energy that manifests magnetic, chemical, mechanical and thermal effects; and what is it formed by the interaction of positive (+) and negative (–) electric charge*
= *The physical phenomenon associated with the existence and interaction of electric charge, whether static (electrostatic) or in the form of flows of electric charges in motion (current)*

¹ <http://dexonline.ro/definitie/electricitate>

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X Static electricity is the friction electric energy

- + a body receive electrons, and the other loses electrons
- + stored in an insulated conductor, in which the electric charge is in a state of tension

X a flow of free electrons passing through a conductor

- + current can pass in two ways:
 - + direct or constant current (DC)
 - + or alternating current (AC)

Direct Current (DC)

- ✗ Constant unidirectional flow of electrons
Ex: between anod (-) and catod (+) of a batery
- ✗ Known as galvanic current

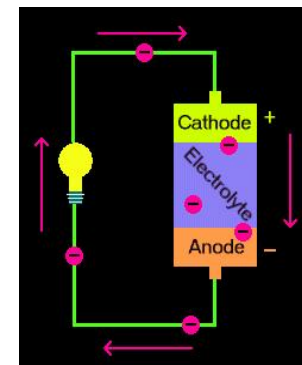


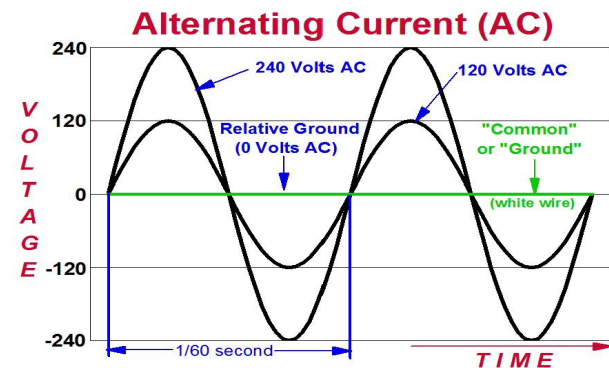
Fig.3. The anode and cathode of a battery¹

¹ source: <http://www.qrg.northwestern.edu/projects/vss/docs/power/2-how-do-batteries-work.html>)

Alternating current (CA)

- ✗ Flow of electrons that rhythmically changes direction
- ✗ Two terminals of a generator (source) which alternately change from positive to negative

Fig.4. Graphyc representation af an alternating current¹



1.2. Physics of electricity

- ✗ **Matter:** anything that has weight and takes up space
- ✗ **Element:** the raw material of matter (oxygen, carbon, copper, etc.)
- ✗ **Atom**
 - + The unity of an element
 - + The smallest particle of an element
 - + Consisting of: protons, neutrons, electrons and other tiny substances

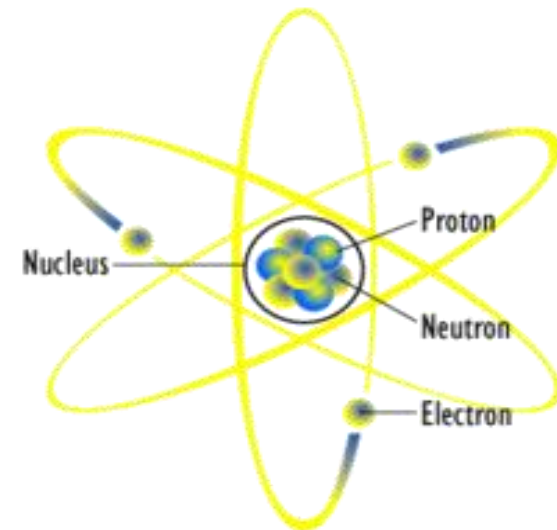
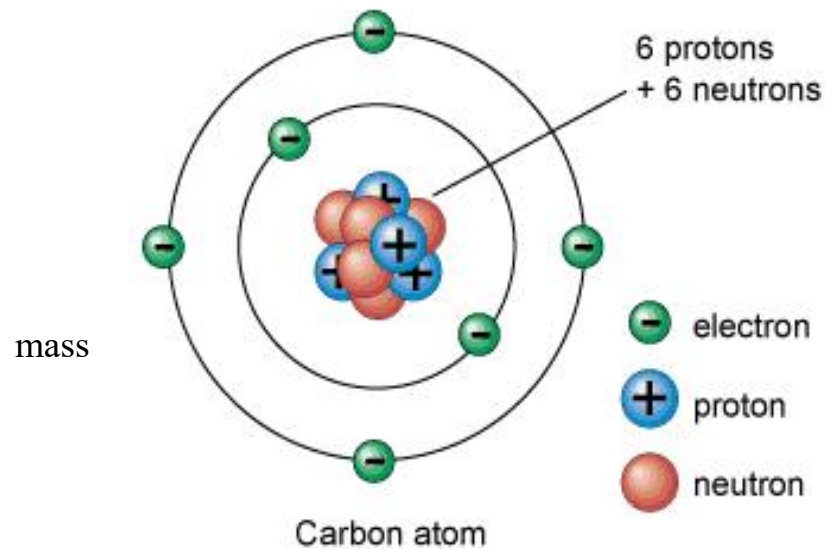


Fig.5. Atom²

¹ source: <http://www.thecoffeebrewers.com/electricity.html>

² source: <http://en.wikipedia.org/wiki/Atom>

- ✗ Molecule
 - + Two or more atoms linked by a chemical bond
 - + Can be identical (O_2) or different (H_2O)
- ✗ Subunits of an atom
 - + Proton
 - + Neutron
 - + Electron



Electron: Located in the orbit of the nucleus, Negligible mass and electric charge -1

Proton: Located in the nucleus of an atom, Mass 1, electric charge $+1$

Neutron: Located in the nucleus of an atom, Mass 1 and electric charge 0

Fig.6. Structure of a carbon atom¹

¹ source: <http://www.universetoday.com/56747/atom-structure/>

Electric charge

- The sum of the charges of the electrons and protons
 - + The difference between the number of protons and electrons
 - + In its normal state: the atom has an equal number of electrons and protons; therefore it is electrically neutral
 - + Chemical, mechanical, solar, or thermal forces cause electrons to be added or removed from the atom, so that it becomes positively or negatively charged.
 - +

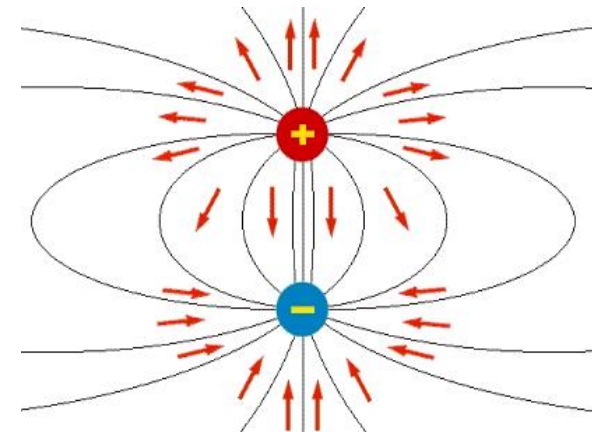


Fig.7 Electric charge of an atom¹

Current flow

- ✗ The flow of an electric charge (the conventional direction of current) from one point to another (from a high concentration of electrons to an area with a lack of electrons)
- ✗ The flow of electrons goes from the positive pole to the negative pole.

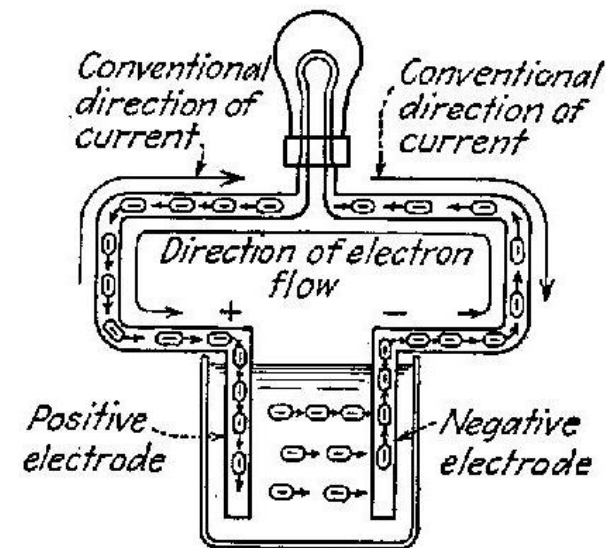


Fig.8. Conventional direction of the current

¹ source: http://en.wikipedia.org/wiki/Electric_charge

Conductor

- ✗ Any substance that can carry electric charges
- ✗ Must have free electrons that can be pushed
- ✗ Metals and water with minerals or electrolytes are the best conductors (good electrical conductors are also good conductors of heat).
- ✗ Electrical conductors do not allow electricity to pass freely. They oppose the flow of electricity by creating resistance.

Isolator

- ✗ Nonconductor
- ✗ Resists the flow of electrons
- ✗ Has no free electrons to collide with
 - ✚ Ex. Glass, rubber, oil, paraffin, pure distilled water

Semiconductor

- ✗ Substances whose conductivity is poor at low temperatures
- ✗ Conductibility increases when
 - ✚ Small amounts of other substances are added
 - ✚ Heat, light, or high voltage is applied
- ✗ Carry a regular flow of electricity
- ✗ Ex. Carbon, silicon, germanium

Partial conductor

- ✗ Substances that allow a certain flow of electricity under certain conditions
 - ✚ Ex. dry wood, paper, tap water, moist air, kerosene

1.3. Quantification of electricity

- + **Coulomb:** Unit of measurement for electric charge, equal to the amount of electricity that passes through a section of a conductor carried by a constant electric current of 1 Ampere in one second. It is produced by the displacement of 6.28×10^{18} electrons (6,280 quadrillion)
- + **Voltage:** The force created by the accumulation of extra electrons at one point in an electrical circuit; usually corresponds to the electron deficit at another point in the same circuit.
 - ✗ If two points are connected, the difference in electron population forces electrons to move from the point with a high electron concentration to the one with a low electron concentration
 - ✗ The unit of force = Volt (V)
 - ✗ The force required to push a current of 1 Ampere (A) against a resistance of 1 Ohm (Ω)
 - ✗ Different sources:
 - ✗ Battery or generator
 - ✗ The voltage coming from a generator is called electromagnetic force (emf)
 - ✗ Commercial electromagnetic devices 110 or 220 V
 - ✗ High voltage transmission lines of 20,000 V
 - ✗ Storm clouds carry several billion Volts.
- + **Ampere:** Unit of current flow equal to the passage of one Coulomb/sec. - i.e. 6.28×10^{18} electrons/sec.
 - ✗ Electromedical intervention requires much less (milliamper, **mA**).
 - ✗ Some therapeutic devices use 0.1 to 1 mA, others use 500 to 1500 mA
 - ✗ **Ohm (Ω)** Unitatea de rezistență sau opoziție față de fluxul de curent continuu
 - ✗ Equal to the resistance of a mercury column of 1 mm² in cross section and 106 cm in length, at 0°C
 - ✗ **Ohm = Volt/ Amp**

Resistance

- ✗ Determined by conductor, according to:
 - + Type of the material
 - + Transversal section
 - + Length
 - + Temperature

Impedance

- ✗ Opposition (resistance) to the flow of alternating current (AC)
- ✗ The ratio between the effective values of the voltage applied to the terminals and those of the current passing through the circuit

1.4. Electric equipment

Generator

- + A device that converts various forms of energy into alternating current
- + A medical device that converts an electrical current input (alternating (AC) or direct current (DC)) into various types of current (AC, DC, or pulsating)

Terminal (pol)

- ✗ The terminal device of a battery or generator
- ✗ Attached via electrode wires (which are attached to the skin)
 - + Positive: the terminal through which the current leaves the generator
 - + Negative: the terminal through which the current returns to the generator
- ✗ **Circuit electric:** Conductor system that allows electrons to move between the poles of the generator
 - + **Closed circuit** - Complete, allowing electrical flow, there are no interruptions in the circuit
 - + **Open circuit** - Interrupted; flow ceases.

2. PHYSIOLOGICAL BASIS OF ELECTROTHERAPY

2.1. Definitions

Electrotherapy (s. f.) Medical treatment based on the action of electric currents as therapeutic agents for certain diseases. – From fr.électrothérapie. (DEX, 1998)

Electrotherapy is a part of therapy with physical agents - physical therapy - in which various forms of electromagnetic energy are applied externally to the human body, with the aim of limiting some physiological processes, strengthening a weaker physiological response and combating pain. (Adrian Dragan, 2007)

Electrotherapy can be used for medical purposes because the human body works mostly electrically.

Electric current = deplasare a sarcinilor electrice printr-un conductor.

Electric conductors :
- grade I – metallic
- grade II – electrolytes
- grade III – gasiform

The human body consists of 70-80% H₂O.

H₂O = H⁺OH

Na⁺, K⁺, Mg, Ca⁺, Cl⁻

2.2. Physiological bases of electrotherapy

The mode of action of physical agents on the human body can be interpreted and evaluated starting from the knowledge and understanding of the fundamental notions of electrophysiology of neuromuscular tissues, considering the fact that any agent applied to the living organism constitutes a stimulus that causes a tissue reaction.

There are two fundamentally different categories of stimuli:

- natural or "appropriate" stimuli (which include the changes that take place at the level of nerve endings, at the level of synapses or through receptors that can trigger nerve impulses);
- artificial or "inappropriate" stimulus (pressure, hitting, light, sound, thermal stimulus, electrical stimulus - this stimulus occupies a special place, due to the fact that they directly touch the potential of cell membranes, interest numerous receptors and cause reactions analogous to those obtained with specific stimulus).

The ability of living cells to react to a stimulus is called **irritability**. As a primary reaction to a stimulus, a local response occurs, and excitability is considered as a secondary reaction of tissues, representing further transmission of the stimulus by cells and nerve fibers.

To trigger an excitation, the stimulus must have a precise minimum intensity – **threshold intensity** – and must act for a certain minimum time to cause excitation. Only "above-threshold" stimulus can cause a response that propagates as an excitation wave that can be measured at a determined distance from the site of excitation. The minimum intensity required to trigger the excitation represents the so-called "**continuous current threshold**" or **REOBASE**.

If more or fewer cells are excited by electrical stimuli – according to the intensity of the electricity and the stimulated surface – a stronger or weaker muscle contraction is observed.

2.2.1. Resting potential (membrane potential)

At rest, the chemical and physical processes in the cell membrane are in a state of equilibrium. Stimulation permanently transforms this (equilibrium) state and causes a series of physical and chemical processes.

At the level of the cell membranes, there is a characteristic distribution of ions, with sodium (Na) and potassium (K) ions having a decisive role, located in different concentrations on either side of the cell membrane. This difference is maintained by the mechanism called the "pump", which consumes energy.

At rest, the cell membrane has an electric potential between (-70) and (-90) mV. This electric potential is generated by the asymmetry of the ion distribution. The distribution asymmetry is determined by passive transmembrane ion transport (through electrochemical potential) and active (through pumping, powered by the metabolic energy stored in ATP).

♦ The negativity inside the cell is due to the organic anions that remain permanently intracellular.

The resting potential is characterized by a high concentration of potassium ions (K^+) inside the cell, and a high concentration of sodium ions (Na^+) outside the cell. This distribution is due to an unequal permeability at rest for potassium and sodium ions, respectively the ratio is K/Na of 1/0.04 (or at 100 K ions, only 4 Na^+ ions penetrate the cell membrane).

2.2.2. Action potential

Excitation production requires a certain intensity of the excitation current to exceed the "threshold" value. In excitation, an important role is played by the surface of the stimulated membrane, the intensity of the current reported per surface unit, realizing the current density.

♦ Following an excitation, if the stimulus exceeds the "threshold value" in terms of intensity and duration, depolarization is triggered, which has two phases:

- phase **a**: Na^+ ion entry,
- phase **b**: Na^+ explosive ion entry and K^+ ion release.

Following this process, the concentration of Na ions exceeds the concentration of K ions, and the internal electric charge reaches (+30) mV. So an action potential is reached, which increases from (-90) to (+30) mV: so, in absolute value, the action potential will be (90 + 30) of 120 mV.

- Between 0 – (+30), the so-called "peak" (overshoot) appears.
- Reaching the (+30) mV value triggers repolarization, which through the action of the $Na-K$ pump (active process) causes Na^+ ions to leave and K^+ ions to enter, thus restoring the resting potential.

♦ So, the electric current that represents an excitation at the level of the cell membrane determines the modification of the properties of the cell membrane, thus the depolarization of the membrane, with the inversion of the membrane potential. The resting potential varies, reaches the critical potential and thus triggers the excitation.

- ♦ Two observations are required:
 1. the fundamental mechanism is represented by the active transport of Na^+ ions inside the cell,
 2. depolarization is progressive, from close to close, according to Hermann's theory.
- ♦ Excess positive charges must be released to restore the resting potential. This is how repolarization occurs, phenomenon due to two mechanisms:
 1. inactivation of the Na^+ pump,
 2. increasing the permeability of the cell membrane for K^+ .

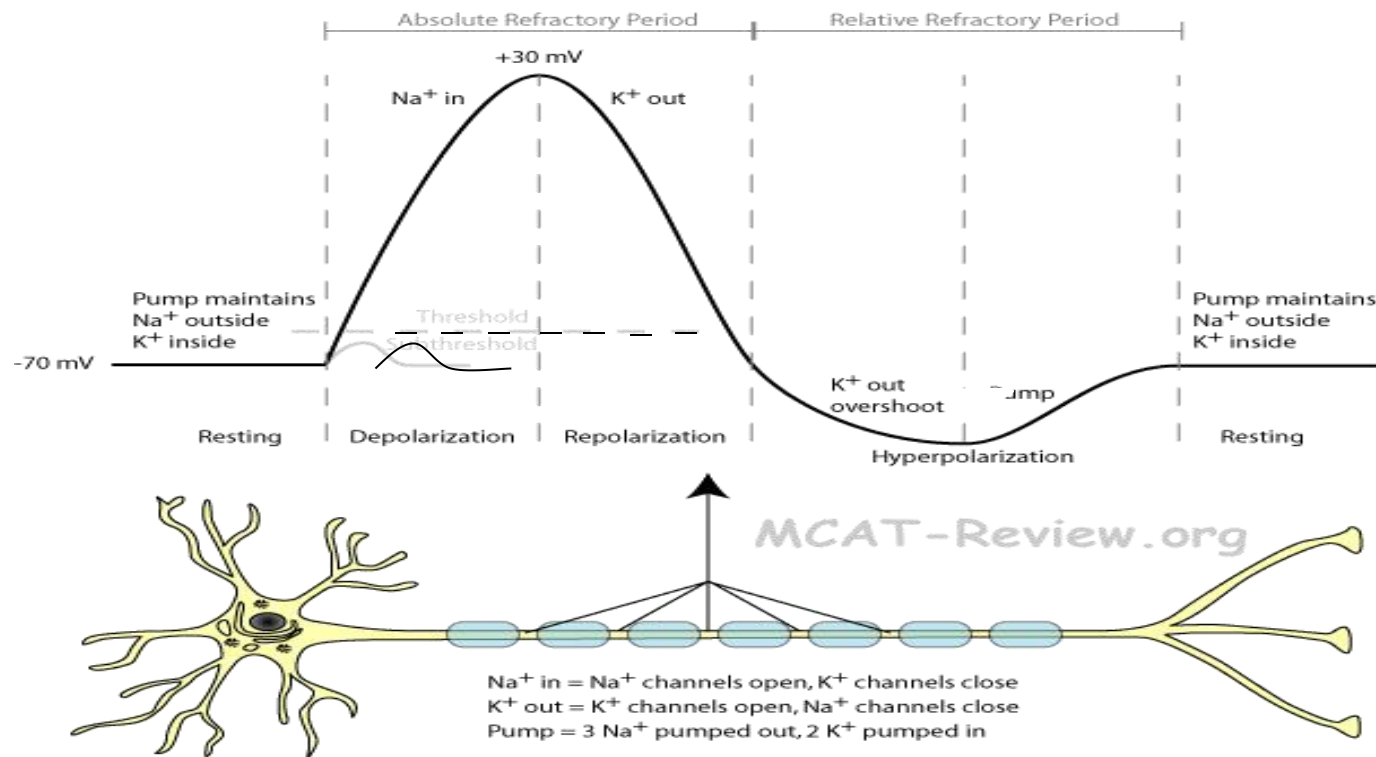


Fig.9. Action potential¹

¹ sursa: <http://mcate-review.org/specialized-eukaryotic-cells-tissues.php>

Action Potential Stages:

1. Resting period: when the cell is at rest, the sodium-potassium pumps ($\text{Na}^+ - \text{K}^+$) maintain the action potential (-70 mV). Sodium (Na^+) much outside the cell membrane, Potassium (K^+) much inside. Ion channels are closed, so the ion gradient does not change.

2. Depolarization: Na^+ channels open, positive sodium enters inside the cell, membrane potential increases up to +30 mV. A lot of sodium inside, a lot of potassium inside.

3. Repolarization: K^+ channels open, sodium channels close, positive potassium leaves the cell, membrane potential decreases. Lots of sodium in, lots of potassium out (opposite of resting period).

4. Hyperpolarization: potassium channels do not close quickly enough, so the membrane potential falls slightly below the resting potential.

5. Refractory period: sodium-potassium pumps work to restore the initial resting period (more potassium in, sodium out). Until this is achieved, the neuron cannot generate another action potential.

Absolute refractory period = from depolarization to restoration of initial resting period.

Relative refractory period = from hyperpolarization to rest period recovery.

Threshold, the all-or-nothing law: When a stimulus exceeds the excitation threshold, an action potential will be triggered. The potential for action is based on the "all or nothing law".

This means that all action potentials have the same magnitude. Specifically, stimulus of different intensities (some barely above threshold, others well above threshold) will trigger the same action potential.

The sodium-potassium pump works like this: 3 Na^+ ions out / 2 K^+ ions in = net positive on the outside, which makes the cell membrane more negative on the inside, the membrane potential being therefore negative.

2.2.3. Electrotonus

In the process of excitation, there are characteristic changes in the physical and physiological properties of the tissues, determined by the direction of the current, called ***electrotonus***. Changes occurring at the level of the negative pole are called ***catelectrotonus***, and those occurring at the positive pole are called electrotonus.

The excitability threshold is lower in the cathode area, as it acts by depolarizing the membrane, facilitating the influx of ions and thus the occurrence of excitation.

At the anode, positive charges increase on the external surface of the membrane - a hyperpolarizing effect occurs with the occurrence of excitation becoming more difficult; tissue excitability decreases, and in the case of a strong anelectrotonus, excitability is abolished by anodic hyperpolarization blockade.

Catelectrotonus - occurs at the cathode (-)

- lowers the excitability threshold
- increases excitability

Anelectrotonus - occurs at the anode (+)

- increases the excitability threshold
- decreases excitability (hyperpolarization)

2.2.4. The Law of Polar Excitability

In applications of direct electricity and low-frequency stimulation, electrical excitations always occur at one of the two poles. Stimulation at the negative pole causes a reversal of the resting potential at the membrane level, leading to the displacement of intracellular sodium, which results in the appearance of an excitation called the cathodic concentration phase (cathodic concentration sequestration).

At the anode, when the current passes, a hyperpolarization occurs, and when the current is removed, the membrane rapidly transitions from the hyperpolarized state back to the resting potential, causing the appearance of an excitation called the anodal break excitation (anodic interruption shock). These manifestations represent Pflüger's Law of Polar Excitability.

Characteristics of Electric Excitants that Condition the Reaching of the Membrane's Critical Threshold

In the case of "step" current pulses, G. Weiss established an approximate relationship between the intensity (I) and the duration (T) of stimulus that produce the minimal response.

Based on Weiss' Law, the following electrophysiological parameters are defined to characterize the excitability of nerves:

Rheobase=the minimum current intensity that can produce excitation over an indefinite period of time.

Stimulus Duration (Useful Time): The excitatory current must have a minimum duration necessary to transport a sufficient amount of energy to alter the resting potential at the level of the excitable membrane. This minimum time is called the "**useful time**"; the greater the intensity, the shorter the useful time, and vice versa.

Chronaxia: The minimum useful time required to produce a minimal excitation with a current whose intensity is equal to twice the rheobase. Its value varies depending on the type of nerve fibers:

- thick myelinated fibers (A) with high excitability have a chronaxia of about 0.1–0.2 ms.
- thinner myelinated fibers have a chronaxia of about 0.2–0.3 ms.
- unmyelinated fibers have a chronaxia of about 0.4–0.7 ms.

Motor chronaxis. For a nerve impulse to pass from a nerve to its effector muscle, there must be neuromuscular isochronism (equal chronaxes), or a ratio between the chronaxes of the nerve and that of normal striated muscle.

Depending on the value/duration of the chronaxis, there are:

- short chronaxis = 0.06 – 0.16 ms
- average chronaxy = 0.20 – 0.36 ms
- long chronaxy = 0.40 – 0.72 ms.

The chronaximetric values of striated muscles are different according to their function and topography, as follows:

- the chronaxis of muscles with faster activity (phasic, reaction) is shorter than those with slower activity (tonics, strength);
- the chronaxis is shorter in the flexor muscles than in the extensor ones;
- the chronaxis is lower at the proximal motor points of a muscle, compared to the distal ones;
- the chronaxis of the upper limbs is smaller than that of the lower limbs;
- the chronaxis of the ventral musculature of the trunk is smaller than that of the dorsal one.

Physiological chronaximetry values can be influenced by a number of constitutional and environmental factors:

- age (under 5 years shorter chronaxis);
- the structure and function of the muscle; the balance of electrolytes (in hypocalcemia it decreases);
- cortical reactivity;
- neurovegetative balance;
- posture;

- ambient temperature.

Apart from motor chronaxy, sensory and sensory chronaxys are also mentioned. The chronaxis of the motor nerves are similar to those of the corresponding sensory nerves, and the chronaxis of the sensory nerves is greater than that of the motor nerves.

Cronaxia is important in the study of the excitability characteristics of the effector nerve-substrate and with particular application in the diagnosis and treatment of neuro-muscular disorders.

2.2.5. Frequency of stimulus

Another important element in the production of electrical excitation is the frequency of the stimuli. The very rapid succession of impulses cannot cause the appearance of excitations, when the excitable structure is in the refractory phase.

Smooth muscle responds only to a stimulus with a very smooth slope of current increase, because it does not show the phenomenon of accommodation, characteristic of striated muscle fiber.

It is necessary to carry out a precise diagnostic evaluation of the treated substrate before the establishment of a neuromuscular electrotherapy:

- the excitation phase – studied by chronaximetry;
- muscle activity (contraction) phase - by electromyography;
- synthesis excitation – contraction – by stimulus – detection;
- the neuromuscular junction is appreciated by the ratio between the chronaxis of the nerve and the muscle.

The frequency of applying the stimuli will also have to consider the nature of the vegetative innervation of the excited structures.

Organs innervated by the parasympathetic, motor plate and CNS synapses require a higher frequency of excitations (cholinergic synapses), because the acetylcholine released at the synapses as a mediator is inactivated in a very short time, while the inactivation of the catecholaminic mediator at the adrenergic synapses (postganglionic sympathetic) requires a longer time.

2.2.6. Changes in excitability

Increased excitability occurs under physiological conditions following arousal. The decrease in Ca ions produces a significant increase in excitability, the increase in extracellular ionic K has a similar effect.

The decrease in excitability is manifested during the absolute refractory and relative refractory periods of the excitation process; the excess of ionic Ca as well as the deficiency of K ions in the extracellular fluid are membrane stabilizing factors and moderators of excitability.

A number of substances such as local analgesics depress excitability by decreasing cell permeability, general anesthetics such as ether and chloroform depress excitability by altering Na⁺ ion transport.

2.2.7. Transmission and conduction of excitation

The way the excitation is conducted differs depending on the type of nerve fibers traversed: unmyelinated or myelinated.

In unmyelinated fibers, excitation is continuously transmitted by near-to-near propagation of "local currents," which occur within the excited area, act on neighboring areas, producing a progressive depolarization, then a repolarization. Local electrical currents cross the entire surface of the axonal membrane and close through the axoplasm and the interstitial fluid, circulating outward from the resting regions to the active portion of the fiber, and through the axoplasm in the opposite direction. After further transmission of the change in membrane potential, the "quietness" of resting equilibrium is restored at the starting point of the excitation.

In myelinated fibers the excitation is transmitted hoppingly; these fibers are wrapped by a myelin sheath made up of concentric layers, which acts as an insulator for the electrical current.

From place to place, she is "cooked" by some "strangles", called "nodes of Ranvier", where ions pass 500 times more easily than through the membrane of unmyelinated fibers, where the myelin sheath breaks. The impulse is propagated from node to node in both directions, in a hopping manner and at a speed much higher than the conduction speed in the unmyelinated fibers.

Saltatory conduction also exhibits very low energy consumption for repolarization during conduction of the depolarizing wave. In both unmyelinated and myelinated axons, impulse conduction occurs bidirectionally, both orthodromic (from the dendrites to the synaptic boutons of the axon) and antidromic.

2.2.8. Neuromuscular transmission

The muscle forms an indissoluble functional assembly with the nerve that controls it, as a "motor unit" with the character of a functional unit. This assembly consists of the motor neuron in the medullary anterior horn, its axon and collaterals, and the afferent muscle fibers with all their respective synapses.

Excitation-contraction couple. The passage of the impulse from the nerve to the muscle is done through the so-called "synaptic valve", which allows the passage of the electrical stimulus represented by the electrical excitation or action potential. It propagates in the muscle in both directions – orthodromic and antidromic.

The contraction of the fibrillar apparatus of the muscle cell is generated by the excitation process that penetrates into the depth of the myofibril through the transverse system of filaments of the sarcomere; Ca ions are released by depolarization in the sarcoplasmic reticulum (which has a functional role in conducting excitation within the fiber to the contractile apparatus), causing myofibril contraction by activating actomyosin.

2.3. Characteristics of the electric current used in therapy

Electrotherapy uses electric current to obtain physiological and therapeutic effects on the human body. The human body, like other living organisms, is a second-class conductor, at the level of which the electric charge carriers are ions. The electric current is characterized by a certain intensity and a certain voltage: it will pass through the body, which in turn will oppose a certain resistance to the passage of the current.

At the cellular level, the electric current represents a stimulus, which, if it exceeds the excitability threshold of the cell membrane in terms of duration and intensity, triggers the depolarization of the membrane that causes a response at the substrate level, depending on the type of excited cell: contraction, nerve impulse, variation in circulatory flow, secretion, etc.

Electric current is of two types: direct electric current and alternating electric current. Alternating current is characterized by frequency.

The frequency represents the number of cycles (stimuli) made per unit of time - if the expression is per second (number of cycles/second) the unit of measurement is the Hertz (Hz).

The period represents the time duration of a cycle, so it is the inverse of the frequency.

The mathematical relationships between the two parameters are as follows:

ν (frequency) = number of cycles / second,

T (period) = $1 / \nu$ (frequency).

The application of electricity can be done either directly - through direct or alternating current and their derivatives, or indirectly - transformed into other forms of energy: radiant, caloric, light, etc. (Dragan Adriana, 2007)

2.3.1. Stimulation and excitability

The current of a certain intensity (I), suddenly installed, is required to operate for a determined time (T) to produce the depolarization of the membrane - a certain amount of electricity (Q) being necessary to trigger the flow of ions:

$$Q = I \times t \text{ where}$$

Q – amount of electricity [C]
 I – current intensity [A]
 t – time [s]

2.3.2. Accommodation. The slope of the excitation pulse

If the increase in current intensity is made over a prolonged time interval, excitation does not occur, even at high current intensities.

This is explained by the installation of a process of accommodation of the excitable tissue. So, for stimulation, the following are important:

- current density [C/cm²]
- the rate of increase of the current intensity [A/s]
- the length of time during which the current flows.

Nerve fibers and muscle fibers behave differently in terms of the accommodation process.

Somatic nerve fibers and striated muscles innervated with intact nerves accommodate very well. The accommodation possibilities of the muscle fiber without nerve connection are very small. Because of this, denervated muscles lack accommodation, they cannot accommodate to smooth-slope impulses.

The accommodation coefficient α is a quantity that appreciates the accommodation phenomenon. To establish it, the intensity of the stimulation threshold is determined for rectangular current compared to triangular current. Its normal value is between 2 and 6. When accommodation is lost, the accommodation coefficient approaches the value of 1.

The skin has a potential difference between the stratum corneum and the dermis of 23 mV. Damaged skin areas have a lower potential difference. Wound healing can also be controlled by electrical signals. (Dragan Adriana, 2007)

2.3.3. Spreading the current in the body

The way in which therapeutic electric currents spread in the body has the following characteristics:

- regardless of the place where the electrodes are placed, the lines of force of the current spread throughout the body, with the largest amount passing through the areas that offer the least resistance;
- in the region between the electrodes, the current intensity is not equal, but proportional to the electrical conductivity of the tissues;
 - the further a segment is located from the electrodes, the intensity of the current reaching it is lower;
- a tissue is not a uniform conductor, because the cell membrane and intercellular spaces offer different resistances to the passage of electric current;
- the electrical conductivity of a tissue is directly proportional to its water content. From this point of view the cerebrospinal fluid, lymph, bile secretion, blood, are the best conductors of electricity; bad conductors are fat and bone tissue.

Mode of penetration of currents into tissues

Electric currents penetrate tissues differently depending on the type of current:

- the galvanic current and the low-frequency alternating current spread exclusively in the intercellular space, because the cell membrane opposes them;
 - the high-frequency alternating current does not encounter resistance from the cell membranes. (Drăgan Adriana, 2007).
- 2.4.

2.4. Classification of electrotherapy

- Low frequency currents $\nu = 0 \div 1000$ Hz
Galvanic current (continuous) and impulse current
- Average frequency currents $\nu = 1000 \div 100,000$ Hz (Gildermeister and Wyss)
- Medium frequency currents and interference currents
- High frequency currents (electromagnetic fields) $\nu = > 300$ kHz (Nerst)
Microwave, shortwave
- Phototherapy: - infrared, ultraviolet, laser radiation
- Mechanical waves: ultrasound
- Magnetic fields: magnetic stimulation, magnetotherapy (Dragan Adriana, 2007)

Classification of electrotherapeutic agents according to Key Watson (source: Watson, 2012, Key Concepts in Electrotherapy)

Electrical Stimulation Agents / Methods	Thermal Agents / Methods	Non-Thermal Agents / Methods
Transcutaneous Electrical Nerve Stimulation (TENS)	Infrared Irradiation (IRR)	[Pulsators] Ultrasound
Interferential Therapy (IFT)	Short Wave Diathermy (SWD)	Low Intensity Pulsed Ultrasound (LIPUS)
Neuromuscular Electrical Stimulation (NMES)	Microwave Diathermy (MWD)	[Pulsator] Short Wave Therapy (PSWT)
Functional electrical stimulation (FES)	Other RF Therapies [Pulsers]	Laser Therapy (LLLT / LILT)
Faradic stimulation	Hydrocollator Packs [Pulsators]	Microwave therapy
Iontophoresis	Paraffin	Low intensity RF applications
High-Voltage Pulsed Galvanic Stimulation (HVPGS)	Balneotherapy (spa/pool)	Pulsed Electromagnetic Fields (PEMF's)
Low Intensity Direct Current (LIDC) and Direct current of low pulsating intensity	Fluid therapy	Microcurrent therapy
Monophasic stimulation	Therapeutic ultrasound	Magnetic therapy
Dynamic pulsating therapy	Laser therapy	
H-wave therapy; Action potential system (APS)		Static magnetic therapy
Russian stimulation: medium frequency stimulation	Cryotherapy / Immersion therapy	Microcurrent therapy
Rebox Therapy; Scenar therapy		
Microcurrent Therapy (MCT)		

2.5. Characteristics of the currents used in electrotherapy

POLARITY

A direct current applied to the tissues leads to the accumulation of positive ions under the cathode and negative ions under the anode. Changes in pH occur locally (under the cathode it will be more alkaline and under the anode more acidic) which causes discomfort to the patient (especially at the cathode). An alternating current does not lead to such an accumulation of electrical charges under the electrodes, and so this current has no polar effects.

The amount of electrical charges moving in each direction of the electrodes can be:

- unequal - the current has polar effects (polar current)
- equal — the current has no polar effects (apolar current)

FREQUENCY: Represents the number of oscillations per unit of time. It is measured in Hz.¹

Pulsed currents have 2 types of frequency:

1. number of oscillations per second
2. number of pulse trains per second "burst frequency"
 - pulse frequency: 60 Hz
 - burst frequency: 2 Hz

It is important to follow the stimulation of the muscles: at a frequency of approx. 30 Hz the tetanic contraction with increased force is obtained.

IMPULSE DURATION: It is closely related to the amplitude in the production of an action potential. At the same amplitude, variable pulse duration can give motor stimulation, pain or sensory stimulation.

PULSE SHAPE: In rectangular pulses, the current intensity rises suddenly to a maximum level, which generates the action potential. If the pulse intensity increases progressively, the phenomenon of current accommodation occurs.

IMPULSE AMPLITUDE: It is between 10 – 100 mA for the currents used in electrotherapy. It depends on the goal of the treatment and the patient (it is set in collaboration with the patient). Amplitude determines the total number of nerve fibers activated.

¹ Ex. : 10 pulsuri pe secundă reprezintă o frecvență de 10 Hz .

EFFECTIVE STIMULATION CYCLES (Duty-cycle):

It represents the ratio between the time when the current is on and the total time until the next impulse or train of impulses (burst). Duty-cycle is important because it is a factor that determines neuromuscular fatigue (neuromuscular fatigue caused by neurotransmitter depletion). Duty-cycle can be measured both at currents with pulses (isolated) and at currents with trains of pulses (burst).

MODULATION: Represents the variation of some parameters: frequency, amplitude, duration.

It aims to reduce the accommodation phenomenon. Accommodation is the decrease in the response to a repeated stimulus and consists in the decrease in the sensory perception of the stimulus. It is important to prevent accommodation when electrical treatment is aimed at pain control. And the impulse trains can be modulated, for example to achieve a muscle contraction as physiological as possible. (Drăgan Adriana, 2007).

2.6. The characteristics of the electrodes

Monopolar application

- 2 electrodes with unequal sizes
- the active or stimulating electrode is placed over the target area.
- the second electrode, the dispersive/indifferent one is placed on an area away from the target area
- usually the active electrode is smaller than the dispersive/indifferent electrode.
- this technique is used for iontophoresis, wound healing and edema treatment

The bipolar application

- 2 electrodes of equal size placed over the area to be treated
- they are used in single-phase or two-phase current applications
- the technique is used in muscle hypotonia, neuromuscular facilitation, spasms, increasing the range of motion

Quadruple application

- 4 electrodes equal in size
- 2 electrodes coming from two separate circuits are positioned so that the currents coming from the two circuits intersect in the target area
- the technique is used to apply interference current

2.7. General indications for the application of electrotherapy procedures

Electrotherapy, through its various forms of application, is useful in all types of pathology:

- ❖ chronic rheumatic disease
 - inflammatory
 - degenerative diseases of the spine and associated syndromes – including lumbosciatica, degenerative and/or post-traumatic joint diseases of the belts and limbs;
- ❖ abarticular rheumatic diseases (muscles, tendons, fascia, synovium, etc.);
- ❖ peripheral nerve diseases (neuralgias, neuritis, polyneuritis, traumatic injuries and their sequelae);
- ❖ central motor neuron injuries - hemiplegia, paraplegia;

Adapted electrical procedures are very useful as associated therapy in the treatment of complications of chronic diseases of the apparatus and systems: cardiovascular, respiratory, digestive, urinary (arterial hypertension, veno-lymphatic insufficiency, respiratory insufficiency, chronic Broncho pneumopathy, bronchial asthma, lithiasis, chronic cholecystopathy, chronic colitis, etc.).

Under these conditions, electrical procedures are useful both in the basic treatment of these ailments, and when these ailments accompany other impairments of the locomotor apparatus indicated for physical-kinetic recovery.

3. PAIN CONTROL AND SELECTIVE STIMULATION

3.1. Introduction

According to the IASP (International Association for the Study of Pain), pain represents "the unpleasant sensory and emotional experience, determined or related to real or potential tissue damage or described in terms that refer to such damage".

Regarding the classification of types of pain, there are several possible criteria.

- depending on the location, the pain can be somatic or visceral
- according to the way of propagation, the pain is primary or secondary – through irradiation along the nerves,
- depending on its duration, the pain can be acute, subacute or chronic.

Pain receptors, represented by dendritic endings, are located in skin, muscles, fascia, tendons, periosteum, teeth, mucous membranes and even in visceral organs.

Classification of pain is essential in its assessment and management.

3.2. Physiological pathways of pain

- pain receptors (skin, joints, periosteum, muscles, viscera, meninges, ligaments, tendons)
- related sensitive nerve fibers
- type A δ – myelinated fast fibers that quickly conduct the impulse to trigger defensive reflex reactions
- type C - unmyelinated fibers, slow, conduct pain slowly and give the sensation of deep ("stabbing") pain, imprecise, which does not trigger defense reactions.

Apart from the reflex nervous response, the body responds to pain by releasing chemical mediators that influence the perception of pain. All pain impulses are modulated in the central nervous system until the conscious sensation of pain is formed.

Modulation occurs:

- in the peripheral nervous system
- in the spinal cord
- in the thalamus
- cortical

3.3. Types of pain

The most common types of pain include:

Nociceptive pain: represents the normal response to noxious stimuli or damage to tissues such as skin, muscles, visceral organs, joints, tendons or bones.

The pain can be:

- somatic: musculoskeletal (joint, myofascial pain), cutaneous - well localized
- visceral: internal organs or smooth muscles - diffuse localization, referred
- psychogenic: pain influenced by psychological factors, unrelated to real tissue damage.

Neuropathic pain: pain initiated or caused by a primary lesion or disease of the somatosensory nervous system. Sensory abnormalities vary from deficits perceived as numbness or hypersensitivity (hyperalgesia or allodynia¹), to paresthesia, such as tingling. Examples include but are not limited to diabetic neuropathy, postherpetic neuralgia, pain after spinal trauma, phantom limb pain (postamputation pain), central pain after stroke².

Inflammatory pain: the result of activation and sensitization of the nociceptive pain pathway by a variety of mediators³ released at the site of inflamed tissue. The incriminated pathologies can be appendicitis, rheumatoid arthritis, inflammatory diseases of the bladder, herpes zoster, etc.

3.4. Pain intensity

A numerical scale from zero (0) to ten (10) is used to assess pain, where 0 = no pain and 10 = maximum pain intensity. Pain intensity can be classified into:

- mild: $\leq 4/10$
- moderate: 5 – 6/10 severe: $> 7/10$

¹ Allodynia - the appearance of the sensation of pain upon the application of non-painful stimuli, of various modalities (caloric, vibratory, tactile, sound). Allodynia is a sign of sensitization of the nociceptive structures of the nervous system and is found in various neurological diseases (migraine, somatoform disorders of the vegetative nervous system, etc.).

² Stroke

³ Proinflammatory mediators are cytokines such as IL-1-alpha, IL-1-beta, IL-6 and TNF-alpha, chemokines, reactive oxygen species, vasoactive amines, lipids, ATP and other factors released by infiltrated leukocytes, vascular endothelial cells, etc.

3.5. Duration of pain

- acute pain: pain between 3-6 months
- chronic pain: pain that lasts more than 3-6 months or that persists longer than acute pain or after tissue healing is complete
- acute pain on the background of chronic pain: a set of acute pain superimposed on chronic pain or which accentuates chronic pain.

Pain reduction can be achieved in different ways. There are several theories that try to explain the mechanisms of pain reduction. From the point of view of electrotherapy, it is clear that phase duration, frequency and amplitude play an important role.

3.6. Theories of pain

The following three theories are important.

3.6.1 Pain control gate theory / gate control theory (Melzack and Wall)

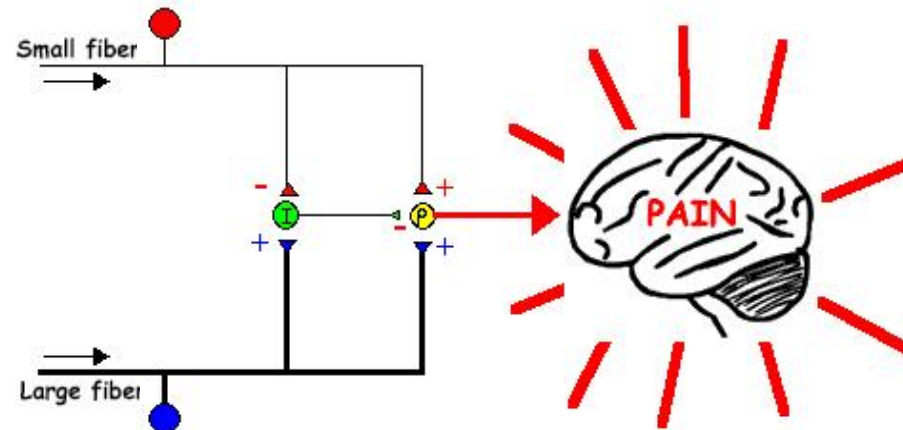
The gate theory of pain control, elaborated in 1965 by Ronald Melzack (a Canadian psychologist) and Patrick David Wall (an English doctor), supports the idea that the perception of physical pain is not the direct result of the activation of nociceptors, it being modulated by the interaction between different neurons. The theory reveals that activation of nerves that do not transmit pain signals can interfere with signals from pain-conducting fibers, inhibiting pain perception to some extent.

The main lines of this theory are still considered valid today, being taken up in another framework by modern models of nociceptive transmission. This theory claims that pain is an expression of the balance between the information that circulates through the spinal cord through the thick nerve fibers and the information transmitted by the thin nerve fibers. In other words, the theory is based on the assumption that stimulation of thick myelinated nerve fibers will cause neural inhibition at the spinal level. This inhibition will block the transport of painful stimuli to the brain that occurs through the thin, unmyelinated nerve fibers. It should be remembered that thick nerve fibers transmit non-nociceptive information and thin nerve fibers transmit nociceptive information. If the activity is more intense in the thick nerve fibers, the pain will be reduced and if there is more activity in the thin fibers, the pain is present.

Table 2. Classification of nerve fibers according to thickness

Category	Efferent	Afferent	Types of sensations	Transmission speed (m/sec.)	Diameter m)
Thick	A - α	I	Proprioception, somatomotor	70 – 120	12 – 22
	A - β	II	Touch, pressure	50 – 70	5 – 12
	A - γ	II	Stretching of motor spindles	30 – 50	5 – 12
Thin	A - δ	III	Pain, cold, touch	< 30	2 – 5
	B	-	Autonomic preganglionic	3 – 14	1 – 3
	C	IV	Thermal pain, mechanoreceptors Autonomic postganglionic	< 3	0.1 – 1.3

The following diagram shows this gate theory of pain control.

**Fig. 10. Gate theory model of pain control¹**

I = inhibitory interneuron; P = projection neuron; "-" = inhibition; "+" = excitation (activation)

¹ source: <http://faculty.washington.edu/chudler/pain.html>; access date: 14.01.2014

1. Without stimulation, both thick and thin fibers are not active, inhibitory neurons block the signal to the projector neuron that makes the connection with the brain. Therefore, the gate of control is closed and, consequently, there is no pain.

2. Stimulation of non-painful receptors causes the activation of thick nerve fibers. They activate the projection neuron (P), but also activate the inhibitory neuron (I), which blocks the signal of the projector neuron that connects with the brain. Therefore, the gate is closed and pain does not arise.

3. Stimulation of pain receptors causes the activation of thin nerve fibers. They activate the projection neuron (P) and block the inhibitory neuron (I). This blockage of the activity of the inhibitory neuron makes it impossible to block the impulse that leaves the projection neuron that connects with the brain. Therefore, the gate is opened and the sensation of **PAIN** appears.

Although the existence of central influence is considered, the gate theory of pain control is still regarded as one of the most important starting points in pain suppression.

3.6.2 Theory of endorphin release (Sjölund and Eriksson)

This theory assumes that, in chronic pain, there is either a hyperactivity of the secretion of endorphins, or an increase in the consumption of released endorphins. The central nervous system can be stimulated to produce these endogenous opiates that cause pain suppression, by applying the current "Burst - TENS"¹ (also known as the more common name of current with low frequency and high intensity, or electroacupuncture - TENS).

According to Sjölund and Eriksson, endorphins are released only at a frequency of 2 – 5 Hz and 7 pulses per impulse.

The amplitude must produce muscle contraction without discomfort (up to the limit of tolerance). Pain reduction through conventional TENS (TENS with high frequency, low intensity) occurs as a result of spinal release of endogenous opiates (endorphins, enkephalins).

3.6.3 Postexcitation depression of the sympathetic nervous system (Sato and Schmidt)

This theory states that postexcitation depression of the sympathetic nervous system can be achieved by stimulating type II and III nerve fibers. In this case, excessive stimulation of type IV fibers should be avoided. In

¹ Transcutaneous electrical nerve stimulation/ transcutaneous electrical nerve stimulation

conditions involving excessive activity of the sympathetic nervous system, emphasis must be placed on the stimulation of type II and III nerve fibers.

3.7. Selective stimulation

It can be seen from the previous presentation of the theories regarding the mechanisms of pain reduction, that there is a general preference for the stimulation of the thick, type II and III nerve fibers. In addition, to obtain muscle stimulation, selective stimulation of the thick nerve fibers of type I ($A\alpha$) of the motoneurons in the anterior horns is preferred. (Howson, 1978; Lullies, 1961).

Howson states that it is advisable to use very short phases to stimulate type II and III nerve fibers, as well as type I ($A\alpha$) motor fibers in motoneurons. The power/duration curve of different types of fibers shows that by using phases with a duration of less than 200 μ s it is possible to stimulate sensory and motor nerves, without stimulating unmyelinated fibers (which transmit pain). In other words, for short application phases, a relatively high amplitude can be selected without stimulating the thin fibers (large amplitude range). On the other hand, in the longer time phases, a small amplitude of the current can stimulate the thin fibers (small amplitude range).

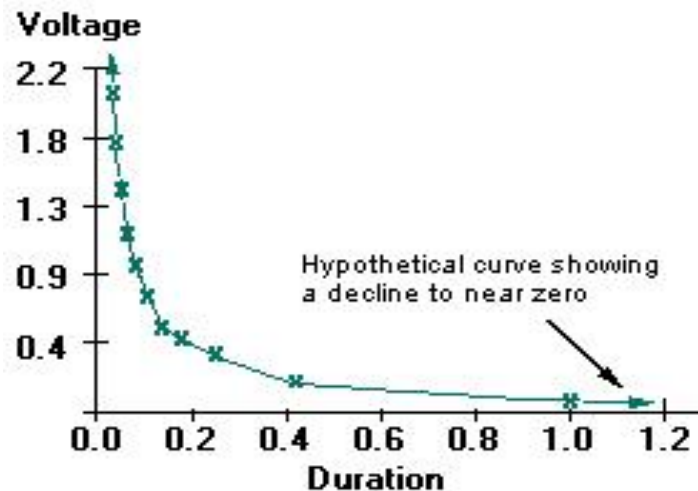


Fig.11. Curve Amplitude/ Duration of stimulation of type I, II, III nerve fibers

3.5. Current amplitude (stimulation level)

Along with the duration and frequency of the electrical impulses, the amplitude of the current is very important to achieve selective stimulation. In electrostimulation, the bibliography refers to various levels of stimulation to establish how high the amplitude must be to truly achieve selective stimulation.

When the amplitude of a current applied to a healthy subject increase, the following reactions occur:

- a. The sensitivity threshold is reached
- b. The motor response threshold is reached
- c. The painful threshold is reached; the patient experiences muscle contraction and pain. .

ATTENTION!!! This principle applies to all types of currents, therefore it is essential to check the subject's skin sensitivity before applying electrostimulation.

The most common classifications used to assess the correct amplitude are as follows:

1. Classification based on the sensation perceived by the patient:

- a. **submitis** (amplitude at which the stimulus is imperceptible);
- b. **mitis** (amplitude at which the stimulus is barely perceptible);
- c. **normalis** (amplitude at which the stimulus is distinctly perceptible);
- d. **fortis** (amplitude at which the stimulus is increased to the limit of tolerance).

A disadvantage of this classification is that it depends exclusively on the verbal information coming from the patient. It also does not consider any motor activity.

2. Classification according to sensory and motor stimulation levels:

- a. **subsensory stimulation level;**
- b. **level of sensory stimulation;**
- c. **level of motor stimulation (clearly perceptible muscle contraction);**
- d. **tolerance limit (strong but still painless muscle contraction);**
- e. **the painful threshold.**

In practice, the latter classification is easier to use. However, it remains an open question whether the motor stimulation is really below the tolerance limit. In pathological cases, the sequence can change. Many factors play an

important role, such as: the nature of the condition, the sensitivity of the patient and the metabolism of the skin. Thus, it is impossible to provide exact boundaries between levels of stimulation. If the aim of the treatment is to produce a motor response, it must be specified whether the amplitude of the current must be increased to the limit of tolerance or to the painful limit.

4. GALVANIC CURRENT

4.1. Definition

Electric current of zero frequency or direct current is called galvanic current. The intensity of the current can vary, increasing from the zero value of the intensity up to a certain level (upward continuous current) or decreasing towards zero (downward continuous current). If these increases and decreases occur rhythmically, the current takes the form of a wavy curve and is called variable current. The continuous electric current used in electrotherapy is called *galvanic current*.

4.2. Production mechanism

- through several methods, the most important being:

• **chemical methods:**

- the classic element for producing direct current is "Volta's cell"
- two bars of different metals - zinc and copper are inserted into an insulated vessel containing dilute sulfuric acid solution,
- by connecting the outer ends of the bars with a conductor, a potential difference of 0.9 V is created (it is 3000 times higher than the one obtained in a dry environment),
- the electromotive force of the direct current is maintained as long as the circuit is closed,
- is based on chemical reactions occurring in the sulfuric acid solution and the electrodes inserted in the vessel,
- the sulfuric acid solution electrolytically dissociates into H^+ ions and SO_4^{2-} radicals, the chemical reactions take place between the ions in the solution and the copper and zinc ions,
- the ions of the opposite sign released accumulate at the level of the electrodes

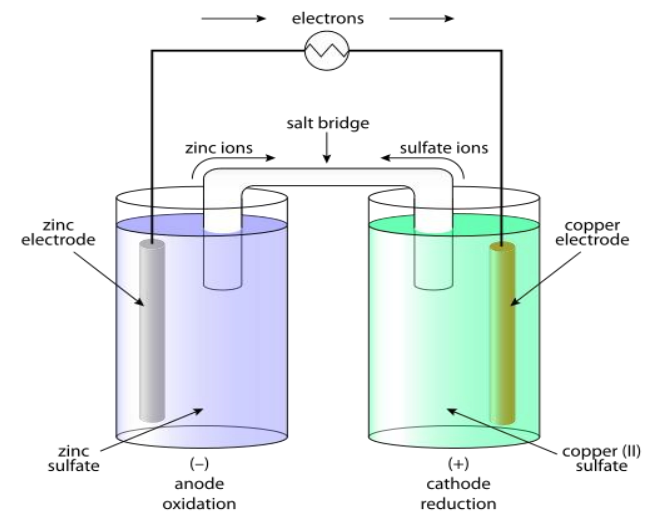


Fig.12. Voltaic pile¹

¹ source: <https://study.com/academy/lesson/types-of-voltaic-cells-batteries-vs-fuel-cells.html>

- **mechanical methods:**

- the transformation of mechanical energy into electrical energy is carried out by the dynamo
- in physiotherapy, a motor-generator is used that transforms the alternating current of 220V from the mains into direct current of approx. 40 - 50V through the mechanical energy of rotation,
- is a pulsating current which, with the help of an electric filter, turns into constant direct current.

- **thermoelectric methods:**

- diodes with two electrodes: - anode in the form of a plate,
- cathode in the form of a spiral filament, both in a glass flask,
- the movement of the electrodes takes place only in one direction, always from the filament to the plate,
- a potential difference is created between the plate and the filament,
- the migration of electrodes between the cathode and the anode determines the continuous electric current.

4.3. Properties of the galvanic current

- **electrolysis:**

- the phenomenon of ionic dissociation and their movement towards poles of the opposite sign:
- the anions (-) go to the anode (+),
- the cations (+) go to the cathode (-).

- **iontophoresis:** - the phenomenon of movement of ions through semipermeable cell membranes;

- **electrophoresis** - the phenomenon by which chemically neutral elements are charged by absorption with ions ("+" or "-") and migrate under the action of the galvanic current towards the anode (an electrophoresis) or towards the cathode (cath electrophoresis),

- **electroosmosis** - movement of water molecules through the cell wall under the action of direct current,

- **tissue resistance or ohmic resistance or tissue resistivity:** - represents the resistance that direct current encounters when passing through tissues, resistance generated by the phenomenon of polarization,

- **tissue resistance values vary depending on the nature of the tissues:**

- liquids: 80 - 100 ohms/cm,
- muscle: 300 ohms/cm,
- deeper parenchymal organs: 400 - 600 ohms/cm,
- adipose tissue, air: 1000 - 3000 ohms/cm.

4.4. Skin resistivity

- depends on:
 - the intensity of the applied electric current;
 - Ohm's¹ law: $U = I \cdot R$;
 - the application time of the galvanic current; the resistivity decreases gradually and after 30 min. from the application of the current, a dynamic equilibrium is reached;
 - insensitive skin perspiration;
- physiological states (menstruation, sleep, physical effort);
 - biological rhythms;
 - nutrition;
 - various pathologies (depression, hypersympathetic tone, epilepsy, myxedema², scleroderma³)

4.5. Biological actions of galvanic current

The fundamental mechanism is the modification of the ionic concentrations at the level of the structures traversed by the current, and secondary biological processes appear in the area where the galvanic current passes.

From the electrochemical and conductivity point of view, the human body behaves as a second-degree conductor, so it can be compared to an electrolyte. In its structure, water represents 70% of the body's weight, the rest being solid substance largely represented by salts. So, in this liquid environment there are many dissolved salts, achieving various concentrations.

¹ Ohm's law applies to electrical conductors across which electrical voltages are applied. Ohm's law states that in a circuit the intensity (I) of the electric current is directly proportional to the applied voltage and inversely proportional to the resistance (R) in the circuit. The mathematical formula of Ohm's law is: $I = U/R$, where: I is the current intensity, measured in amperes; U is the applied voltage, measured in volts; R is the resistance of the circuit, measured in ohms. In other words, in the case of a resistor whose resistance is constant, if the voltage increases, the current will increase proportionally to the voltage and vice versa. Such a resistor that faithfully obeys Ohm's law is called an ohmic resistor.

² Cutaneous infiltration causing swelling of the face and limbs, being characteristic of hypothyroidism (reduction of thyroid gland activity). Myxedema is a hard, elastic edema that must be distinguished from soft edema from fluid retention in heart, kidney, or liver failure. Myxedema often occurs in newborns, much more commonly in women between 30 and 50 years of age.

³ Scleroderma or "thick skin" is a chronic, autoimmune condition that most commonly affects middle-aged women. It can cause thickening and loss of elasticity of the skin and conditions of the heart, lungs, kidneys and gastrointestinal tract. The disease is caused by an overproduction of collagen in the body's connective tissue. Collagen is normally responsible for keeping the skin and organs supple, but when it is produced in excess, it causes the tissues to become thick and immobile.

The human electrolytic environment is not homogeneous because it is composed of elements with different degrees of conductivity. Under these conditions, the body cannot be uniformly traversed by electric current. There is an older but still current classification, developed by Krilova and Simanko according to which, from the point of view of electrical conductivity, the structures of the body can be divided into 4 groups:

- **Grade I:** very good electrically conductive anatomical structures (blood, lymph, CSF¹, vitreous body),
- **Grade II:** anatomical structures with good electrical conductivity (sweat glands, muscles, subcutaneous tissue, internal organs),
- **Grade III:** poorly conductive anatomical structures (nervous tissue, adipose tissue, sebaceous glands, bone tissue),
- **Grade IV:** very poorly conductive anatomical structures (hair, epidermis).

The application of galvanic current on the body will determine a series of processes differentiated into two large groups: - the polar effects that occur at the level of the applied electrodes,
- the interpolation effects that occur inside the body, in the regions between the two electrodes.

The polar and interpolation effects are concurrent, and the total effect of the current involves the "summation" of the two categories of effects². (Sidenco)

4.5.1. Polar effects

♦ ♦ The polar effects are due to the changes that occur at the point of contact between the skin and the electrodes to be applied. To the greatest extent, the polar effects are the consequence of the electrolysis process. Following this process, acid is produced at the anode (HCl = hydrochloric acid), and base is produced at the cathode (NaOH = sodium hydroxide).

♦ The polar effects are therefore determined by the chemical changes that occur; these changes depend on several parameters: - the quality of the electrode (shape, size, chemical composition);
- the qualities of the galvanic current (intensity, direction, sense, duration);

¹ Cerebrospinal fluid

² Sidenco Elena Luminița, Electrotherapy, course notes, Spiru Haret University, Faculty of Physical Education and Sport, specialization in Kinesiology, source: http://spiruharet.ucoz.com/_fr/0/Electroterapie_.pdf, accessed 22.01.2014

- certain properties of the body (integument condition, electrical resistance, capacity, conductivity of various tissues, general reactivity of the individual).

In case of overdose of electric current, extreme polar effects may occur (burns and necrosis in the area of application). (Sidenco)

4.5.2. Interpolation effects

The interpolation effects are of fundamental importance for electrotherapy because they are the basis of the effects developed in the substrate traversed by the galvanic current. The interpolation effects are determined by physico-chemical tissue changes occurring when the electric current passes through the tissues. (Sidenco)

They are based on processes of:

- **bioelectrolysis**
- **ionoforesis**
- **electroosmosis**

which implies



- changes in membrane potential,
- changes in neuromuscular excitability,
- thermal effects,
- effects of electromagnetic induction,
- changes in the chemical composition of tissues.

4.6. Physiological effects of galvanic current

The effects and biological changes occurring when the galvanic current passes through living tissues are still incompletely elucidated. The effects are mainly based on the reactions developed at the level of easily excitable structures, mainly over the nerve fibers.

The application of the galvanic current with a slope (the introduction is smooth), as happens in therapeutic practice, gives rise to clearly different effects compared to the suddenly entered galvanic current, usually used for diagnostic purposes. This sudden stimulation by galvanic current causes an excitation, which at the level of the muscle fiber is motor, causing contraction, and at the level of the sensitive fiber it causes pain. Even if the totality of the effects could not be completely defined, important biological changes occur that determine physiological and therapeutic effects.

● ***On sensitive nerve fibers:***

When the galvanic current passes, the sensitive receptors in the skin register the tingling sensation, which increases proportionally with the intensity of the current. If the intensity of the current exceeds the level of the tingling sensation, the next sensation developed will be fine pricks and if the intensity is continued, the burning sensation will appear, finally reaching the sensation of pain. After a few sessions, an increase in the threshold of tactile and painful sensitivity is noted, the sensations begin to appear at higher levels of current intensity (this reaction depends a lot on the individual and his own reactivity and his particularities). We thus consider that the galvanic current develops an analgesic action (by increasing the sensitivity threshold for pain), this effect appearing primarily at the positive (+) pole. The explanation of these phenomena is given by the changes in neuromuscular excitability when the galvanic current passes, a phenomenon defined as electrotonus and described by Pflüger.

Thus, at the positive (+) pole, the cell membrane hyperpolarizes and thus the excitability decreases (the excitability threshold increases, so the substrate will react to more intense stimuli, including painful ones), and thus we say that anelectrotonus develops. At the negative (-) pole, depolarization dominates and thus the excitability increases (the excitability threshold decreases, the substrate will react to less intense stimuli, so it will be more excitable), so catelectrotonus develops. The two forms of electrotonus are produced simultaneously, at the level of the two electrodes, when the galvanic current passes.

Electrotonus varies depending on the intensity of the applied galvanic current. It was found that:

- ◆ at low intensities the catelectrotonus dominates,
- ◆ at high intensities, anelectrotonus dominates,
- ◆ at medium intensities there is a balance between the effects

Kowarschick studied very carefully the mechanism of analgesia and found that this action of the galvanic current, developed when the current passes through -- the substrate, is due to the changes that occur between the electrodes as a result of the movement of ions, and that the effect of galvanization on the CNS, as well as on the circulatory system, also contributes to the analgesic action. the sensation recorded depends on the increase in the intensity of the applied current: ***tingling ~ stinging ~ burning ~ pain***

- at the (+) pole, the phenomenon of analgesia is induced, due to the hyperpolarization of the cell and the decrease in its excitability.

- at the (-) pole, the phenomenon of stimulation is induced by depolarizing the cell and increasing its excitability.

- ***On motor nerve fibers:***

At the negative (-) pole, when it is used as an active electrode, the excitability threshold for the motor fibers decreases, so their excitability increases: it will therefore be possible to stimulate the motor fibers and cause contraction. Studies have proven that the sudden decrease or increase in current intensity represents a sufficiently important stimulus, triggering a prompt muscle contraction. The stimulating action of the galvanic current on the motor nerve fibers is used in practice, as preparation of the denervated muscles for the excitatory currents.

At the (-) pole, a decrease in the excitation threshold is recorded, with the same phenomenon of neuromotor stimulation with increased excitability.

- ***On the central nervous system:***

There are definite effects of galvanic current on the CNS first tested in laboratory animals. Hoff experimentally proved that, when applying descending galvanization, with the positive (+) cranial and the negative (-) caudal electrode on the experimental animal, the so-called "dizziness" is produced which can go up to galvanic "narcosis", appearing when the current intensity increases sufficiently. Clinically, this condition was expressed by the fact that the animal's extremities remained extended (the first studies carried out on the frog). If the galvanization had an ascending direction (positive caudal and negative cranial electrode), the so-called "galvanic convulsion" occurs, with strongly flexed extremities. Thus, Hoff proved that the descending applications have a sedative, narcotic effect, and the ascending ones an exciting effect on the CNS of the experiment animal.

The same thing was found in the case of fish: in descending applications (by orienting the head to the anode and the tail to the cathode) a certain disorientation appears over time, while in the case of ascending applications excitation effects appear.

Koeppen extended these studies to humans and showed that descending applications of galvanic current (especially in the case of applications in the form of galvanic baths) decrease the osteotendinous reflectivity of the individual, while ascending applications increase excitability. In conclusion, Koeppen believes that CNS tone is generally diminished in descending applications. (Sidenco)

In conclusion, we can say that when the current is passed, the installed effects depend on the applied polarity, namely:

- the (+) pole applied cranially causes an analgesic, descending effect,
- the (-) pole applied cranially causes a stimulating, ascending effect.

Various studies related to the sensory reactions determined by the passage of the electric current have shown that they can appear as follows:

- ◆ luminous visual reactions of the phosphene type (if the subject sits with his eyes closed), perceived in the form of dots, sticks, colored circles (yellow or other colors);
- ◆ tinnitus-type auditory reactions (pops/noises in the ears);
- ◆ labyrinth reactions of the voltaic vertigo type: the sensation of dizziness perceived by the subject according to which the head deviates to the right if the subject has no impairments that compromise balance, or by the sick side if he has a known suffering at the level of the inner ear;
- ◆ taste reactions: at the negative pole (–) the appearance of a metallic, astringent taste is observed, and at the positive pole (+) appearance of sour taste.

● ***On the vasomotor vegetative fibers:***

The galvanic current causes an important vascular activation, clinically expressed by hyperemia.

Thus, when the galvanic current passes, after a short period of vasoconstriction, a reactive vasodilation occurs that characterizes hyperemia, clinically expressed by local skin erythema, accompanied by an increase in local temperature. Subjectively, a pleasant warm sensation is perceived at the electrode level. A reaction takes place that persists even after the interruption of the electric current, being always more pronounced at the cathode, and which slowly disappears in a few hours.

Local vasodilation is important, both at the level of superficial skin vessels and at the level of deep vessels, first of all muscle vessels. Consequently, when the galvanic current passes, vascularization also increases in the deep territories, following the increase in blood flow in the superficial ones. This has been proven by multiple studies, based on various methods of investigation:

- a plethysmographic,
- an infrasonoscillographic,
- fluorographics, highlighting the blood flows in a territory, as well as the blood flow, at one given moment, through a certain area.

Thus, it was found that, upon the passage of the galvanic current, the skin circulation increases by up to 500%, and the muscle circulation by up to 300% compared to the resting values (before the passage of the galvanic current). The persistence of the phenomenon is 15-30 minutes after application.

The vasodilator effects obtained in this way through the passage of galvanic current are superior to other physical procedures, for example in the field of hydrothermotherapy, such as the application of Hauffe ascending baths (partial baths): the methodology of this procedure involves immersing the upper limbs in a vessel of water, starting from the temperature of indifference (at which heat exchanges between the body and the environment are minimal) and increasing the temperature gradually, one degree Celsius per minute, thus causing vasodilatation in the immersed areas.

Classically, this partial hydrothermotherapy procedure is applied in order to stimulate a vasodilatation process in the coronary territory, similar to that produced at the level of the immersed upper limbs, due to the fact that there is a consensual relationship between the circulation of the upper limbs and the heart, that is, the two territories have a vascular reaction developed in the same direction (they respond in the same way to stimuli, through vasodilation or vasoconstriction, regardless of whether the stimulus is applied to one of the territories, superficially cutaneous or deeply).

The passage of the galvanic current produces a vasodilatation superior to this procedure and others. The increase in local vascularization upon the passage of the galvanic current causes an increase in the irrigation of the respective area and biotrophic effects, thereby increasing the degree of nutrition of the territory, and consequently, increases the resorption of local exudates and edemas.

In conclusion, the effects are of hyperemic action, activation of vascularization (vasodilation both at the level of the superficial, skin vessels and at the level of the deep ones, in the muscle layers), skin erythema. Due to these effects on the peripheral, cutaneous and muscular vasculature, applications of galvanic current are indicated in several types of pathologies:

- ◆ acrocyanosis,
- ◆ angioneuropathy (suffering based on functional disorders at the level of nerve vessels, especially vegetative fillets),
- ◆ nocturnal functional cryoparesthesias, especially of the lower limbs (expressed clinically by numbness, tingling with cold sensation, peripheral vascular changes),
- ◆ peripheral arteriopathy (damages of the main vascular trunks, especially in the early stages, without important organic alterations of the vascular wall, with a decrease in its elasticity and therefore, a vasodilator response),
- ◆ reflex sympathetic dystrophies (the old "algoneurodystrophies") of the limbs, which appear through a mechanism of hypersympathetic tonia, most often triggered post-traumatic. (Sidenco)

● ***On the autonomic nervous system:***

This recognized action of the galvanic current is, however, inconstant and individualized. The vegetative reaction to the passage of the galvanic current depends on:

- ◆ dominance of sympathetic or parasympathetic tone, specific to the individual on whom the application is made,
- ◆ the place of application of the galvanic current,
- ◆ polarity (sympathetic or parasympathetic stimulation, depending on the polarity of the applied galvanic current).

The region of choice, when specifically aiming to influence the function of the vegetative nervous system (VNS), is the upper cervical and dorsal area, generically called "Scerbac's collar": this will be the place of application of the procedure.

● ***On the circulatory system***

Schnee demonstrated for the first time the differential action of the galvanic current on the circulation, depending on the polarity of the application. Descending galvanizations increase blood flow and circulation dynamics to the heart, so:

- increases the return circulation of venous blood from the lungs and from the upper limb,
- increases arterial blood transport to the portal system.

If the application is ascending:

- increases venous circulation from the lower limbs and portal organs to the heart,
- increases arterial circulation to the lungs and upper limbs,
- increases the speed of venous blood from the heart to the lungs.

However, there is an individual reactivity that we must consider during these applications. The final result will therefore depend on the patient's individual reaction to the galvanic current, to which are added the characteristics of the type of application.

Due to these actions developed during the passage of the galvanic current, we believe that the applications of the galvanic current determine the following physiological effects at the level of the substrate traversed:

- ◆ increase in circulatory flow, including muscular flow (several times; secondarily, this increase participates in obtaining the analgesic effect, especially when the pain is based on ischemic phenomena);

- ♦ the development of the effect on the thrombus, provided that the application is done transversely through the vessel (lateral-lateral), always in the same direction:
 - thus, after 2-3 days of application, the volume decreases and the thrombus attaches to the cathode (phase I),
 - and at approx. 5 days after application, recanalization of the vascular lumen towards the anode occurs (phase II); this effect appears only if the application is always done in the same direction;
- ♦ the occurrence of an analgesic effect, as a consequence of several mechanisms:
 1. stimulation of circulation, which mainly leads to combating ischemic type pain,
 2. the decrease in excitability at the anode, so the development of the prevalent analgesic effect at the positive electrode,
 3. improving the accommodation of the striated muscle to the passage of the galvanic current.

All these effects are based, as an intimate cellular mechanism, on the increase in the permeability of the cell membrane and therefore the phenomenon of cellular activation.

The therapeutic effects are based on the following mechanisms:

- ♦ increase in local metabolism,
- ♦ increase in tissue diffusion,
- ♦ the hyperemissive effect, resulting from the actions of the galvanic current on the excitable structures traversed.

These activated mechanisms are translated by:

- ♦ the antiedematous effect, due to the improvement of circulation in all vascular territories (arterial, capillary, and consequently, also venous),
- ♦ the analgesic effect, resulting from the activation of multiple mechanisms (circulatory, metabolic and nervous - both local (receptors) and regional (nerve paths)),
- ♦ correction of local neuro-vegetative disorders, especially through circulatory and metabolic mechanism.

Therapeutic effects of galvanic current

- * analgesic,
- * exciting,
- * stimulating,
- * vasodilator,
- * food,
- * resorptive,

4.7. Methods of application

4.7.1. Simple galvanic bath

Electrodes used for simple electroplating, made of metal plates (lead)/rubber/self-adhesive electrodes, have different shapes and sizes depending on the region to which they are applied and the desired effects. Most often, rectangular plates of equal or different sizes of 6/8, 8/10, 10/15 cm are used.

Electrodes are firmly applied to the skin through hydrophilic gauze wraps soaked in saline or plain water.

If an analgesic effect is sought, the active electrode is the positive one, and if an exciting effect is sought, the active electrode is the negative one.

Two ways of placing the electrodes are used:

- **transversely**, on one side and on the other of the affected region that it thus frames face to face (shoulder, ankle, knee);
- **longitudinal**, with the electrodes placed at a distance, at the extremities of the treated segment (arm, calf, lower limb).

The intensity of the applied current is dosed from the potentiometer according to the tolerance of the individual and the tolerance at the application site, the correct sensation being that of a pleasant tingling sensation. This corresponds to a current intensity of 0.1-0.2 mA per cm² of electrode.

The number of necessary sessions is 8-10 in acute forms and 12-15 or more in chronic ones. The patient must be advised in advance of the sensation he will feel. He will be placed on the treatment couch in the most

antalgic positions depending on the area to be treated. We mention skin burns as possible incidents. They can occur in patients with impaired skin sensitivity. When the direct current is passed, the water in the hydrophilic shells dissociates into H^+ and OH^- . Parasitic ions (Na, Cl, K) are commonly found on the skin, which combine with H^+ and OH^- to produce the respective acid or base, producing a skin burn.

For prevention, protective solutions with the following formulas are used:

- For the positive pole: NaCl 5g, NaOH 1g, Distilled water ad. 1000 ml (for HCl neutralization)
- For the negative pole: NaCl 6g, diluted HCl 6.5g, distilled water ad. 1000 ml (for NaOH neutralization)

The potentiometer of the device from which the intensity of the electric current is regulated is handled very slowly because otherwise painful muscle contractions may occur at the rapid variation of the intensity.

Two plate electrodes can be used, which can be equal in size or not and in this last case, the smaller electrode is the active electrode (-).

* current intensity can be determined:

- subjectively, the patient registering the sensation of tingling, pricking,
- objective, according to the formula $T \text{ (duration in minutes)} \times I \text{ (intensity in mA)}$

* session monitoring:

- duration between 20 - 30 min., daily or every 2 days,
- thermal comfort of the microclimate 22 - 24 degrees Celsius,
- the choice of electrodes depending on the treated region,
- plate electrodes, perfectly smooth, covered with a hydrophilic layer, which exceeds the edges by 2 - 3 cm electrodes,
- electrodes fixed to the skin by elastic bands, rubber bands.

4.7.2. *Galvanic bath*

It is applied to treat larger areas or the whole body. They combine the effect of the galvanic current with the thermal effect of water, which becomes a mediator between the electrodes and the skin. The current density on the skin is lower and therefore there is no risk of skin burns.

A. Partial galvanization

Four vessels or cells are used that are filled with water at 37°, water through which galvanic current will pass. Depending on the purpose, four, three, two or a single cell can be used.

Four-cell galvanic baths use four vessels containing water at 34-38 ° C, vessels that have electrodes embedded in their walls through which direct current flows. The patient can insert two, three or all four limbs into these vessels. The polarity is variable depending on the proposed objectives and the set number of cells.

Depending on the intended purpose, the 4 cellular bathrooms can be:

- *descending*: polarized (+) upper limbs and (-) lower limbs with sedative, hypotensive effect;
- *ascending*: polarized (-) upper limbs and (+) lower limbs, with a slightly exciting and blood pressure-increasing effect.

Water temperature:

- higher, 37 - 38°C - reduces the unpleasant sensation created by the current and allows the application of higher intensities;
- lower, 34 - 35°C - accentuates the unpleasant sensation given by the current.



Fig.13. Partial galvanic bath¹

- * the staff checks the installations before use,
- * the intensity is used "at the threshold" - tingling - in case of neuralgia, myalgia, arthralgia,

¹ source: <http://www.destinatiieuropene.ro/album-foto/bai-galvanice-4120/>

- * intensity above the threshold - pricks - in case of paresis, paralysis, poliomyelitis, varicose disease,
- * in disorders of skin sensitivity and angiospasm, we are not guided by the sensation perceived by the patient and too high an intensity is not introduced, in order to avoid skin burns,
- * duration: 10 min.,
- * daily or every other day, lasting 20-30 minutes.

B. Complete galvanic bath

The Stanger galvanic bath is a tub insulated with plastic material in which there are eight electrodes fixed to the walls.

Galvanic current can be made to flow between these electrodes in multiple ways:

- ✧ ascending,
- ✧ descendent,
- ✧ transversely,
- ✧ diagonally.

he active pole in electroplating is the (+) electrode. The water has a temperature of 37-38°C and a maximum concentration of 2g/l NaCl to be able to conduct the electric current well, and the intensity of the current is adjusted according to the doctor's prescription and the patient's subjective sensation: pleasant tingling or warmth (400-600 mA).



Fig. 14. Full galvanic bath (Stanger bath)

A plastic tub is used, equipped with 8 electrodes: one cranial, one caudal, left-right lateral,

- * Current intensity: 1000 - 1200 mA, of which 1/3 is effective.
- * Duration of a bath of 20 - 30 min., at the rate of one bath every 3 days, 6 - 12 baths

4.7.3. Galvanic ionization (iontophoresis):

* the introduction of various therapeutic substances into the body with the help of galvanic current is called iontophoresis, galvanic ionization, galvanotherapy or ionogalvanization,

* in principle, the medicinal substance undergoes a process of electrolytic dissociation under the action of the galvanic current, with the consecutive movement of the ions towards the poles of the opposite sign,

* the effect of the procedure depends on the concentration of the solution (a concentration of approx. 20 ml.N/10 is recommended for a 100 cm² electrode,

* 0.4 mEq of base (sol. NaOH) is added to the anode for neutralization/buffering and 0.4 mEq of acid (HCl) to the cathode,

* during the ionization session, the ion transfer rate depends on the intensity of the galvanic current up to a certain threshold, variable from individual to individual and is due to the braking phenomenon mentioned,

* if the cathodic solution is acidified beforehand and the anodic solution alkalized respectively, the transfer rate increases up to 75 - 80% for cations and 90 - 95% for anions.

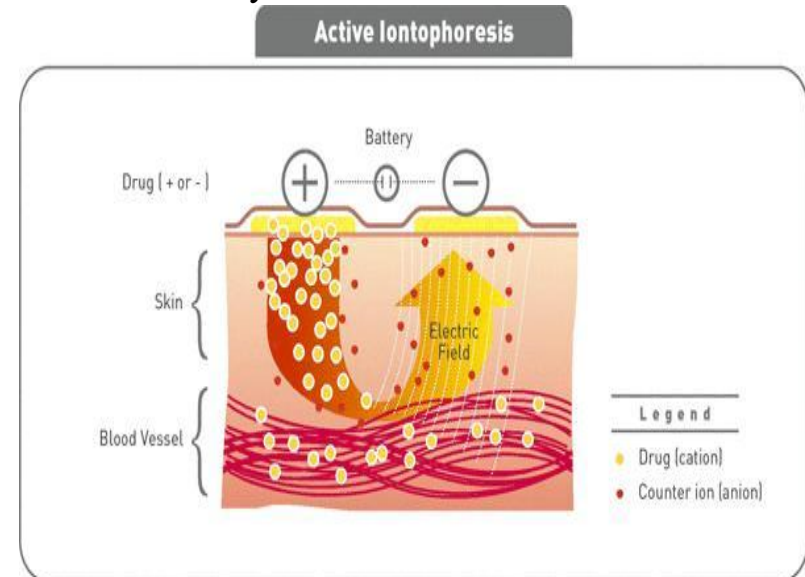


Fig. 15. Iontophoresis¹

Solutions are used that contain active substances that dissociate in the electric field and penetrate the skin at the level of hair follicles and sweat glands, where they make deposits that are then taken over by the blood circulation.

¹ source: <http://houghtonphysicaltherapy.com/Iontophoresis.htm>

Ex.: ionogalvanization with CaCl_2 : The CaCl_2 solution is placed at the anode.

Solutions used for ionogalvanization:

- at the positive pole: CaCl_2 , MgSO_4 , ZnSO_4 , metal ions, alkaloids, acetylcholine, morphine, xylene, atropine, corticoids;

- at the negative pole: salts of organic acids, Br, Cl, I, salicylic acid, acetic acid, oxalic acid or citric acid.

The solutions are prepared with distilled water. The concentration of the solutions is small (1 – 3 %) because in the solution, the electrolytic dissociation is the greater the less concentrated the solution.

4.8. Indications of galvanization

- * nervous system: neuralgia, neuritis, paresis, paralysis, neurovegetative imbalances,
- * locomotor system: myalgias, arthrosis,
- * abarticular rheumatism: tendinitis, bursitis, epicondylitis, periarthrititis, stabilized phase arthritis.
- * cardiovascular system: arteriopathy stages I - II, varicose disease stages I - II, hypertension stages I - II.
- * dermatology: acne, allergy, atonic ulcers, frostbite.

4.9. Contraindications

- * lesions of cutaneous continuity,
- * allergy, intolerance to galvanic current,
- * benign, malignant tumors,
- * skin infections,
- * Cutaneous TB,
- * febrile patients,
- * decompensated organic diseases or at risk of decompensation,
- * patients wearing osteosynthesis materials.

4.10. Example of good practice

- ***In sciatic neuralgia***, longitudinal lombo-plantar electroplating or transversal electroplating on the sciatic is applied. If the pain is only up to the thigh or calf, one lumbar electrode is applied, the other on the back of the thigh or the outer side of the calf,
- ***In neuralgia of the cervico-brachial plexus***, cervico-palmar galvanization is applied,
- ***In gross paralysis of the upper and lower limbs after poliomyelitis, infectious toxic neuritis***, electroplating is applied by placing the active electrode (-) on the injured muscle. Galvanizing is done cervico-palmar, if necessary lombo-plantar,
- ***In myalgias, neuromyalgias with different locations***, place the "+" electrode on the spine next to the neuromuscular segment concerned and the "-" electrode on the painful muscle area,
- ***In arthritis, arthrosis with mono- or oligo-articular localization***, transversal electroplating is done on the large joints,
- ***In tendinitis, bursitis, epicondylitis***, the small, active electrode (+) and the indifferent electrode at a distance are applied to the painful site,
- ***Peripheral circulatory disorders (with a spastic component)*** are well influenced by galvanizations, having a long-lasting vasodilator effect.

5. LOW FREQUENCY CURRENT

5.1. Pulsed currents

Interrupting the direct current - with the help of a manual switch (the first devices) or through electronic regulation (modern devices) - produces rhythmically successive electrical impulses (single or in series) with an exciting effect. It is a current with biphasic asymmetric pulses, with a frequency between 30-70 Hz and a pulse duration of approx. 1 ms. These impulses are used to stimulate normally innervated muscles.

5.1.1. Characteristics

- * shape:
 - sine
 - square
 - triangular
 - trapezoid
- * amplitude
- * frequency
- * impulse duration (t) and pause duration (tp)
- * modulation

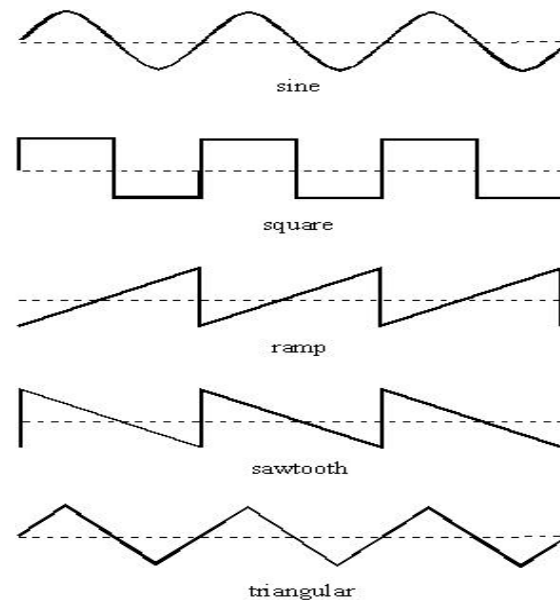


Fig.16. Low frequency current shapes¹

¹ sursa: <http://whatis.techtarget.com/definition/waveform>

5.1.2. Production mechanism

- * there are multiple possibilities for creating and combining impulses by varying their shape, amplitude, duration and frequency,
- * from the rectangular current, derived forms are obtained by:
 - modification of the upper or lower plate,
 - increase or decrease in intensity,
 - the variation of the duration of the impulses and the pause.
- * triangular pulses are produced by "timing" the excitation intensity in the form of ascending and descending oblique linear slopes, longer or shorter,
- * if the upward slope has the shape of a convex curve of special shape (corresponds to an exponential mathematical function), the impulse will be called "exponential",
- * trapezoidal impulses result from the combination of rectangular and triangular impulses (ascending or descending slopes can be linear or curved),
- * the thyatron current is obtained with the help of cathode tubes (it has only positive half-waves with the elimination of the ascending slope = rectified current),
- * diadynamic currents are obtained from the sinusoidal current.

5.2. Low frequency current therapy

5.2.1. Stimulation of the normoinnervated striated muscles contraction

- * by electrical stimulation based on the excitation action of electrical impulses on muscle tissue and nerve fibers,
- * each membrane, depending on the type of cells, has a certain optimal frequency for the threshold value of its stimulation (for example nerve fibers A - 50 Hz; nerve fibers C - 5 Hz),
- * normally innervated skeletal muscles respond to impulses of short duration and relatively fast frequency: - between 0.1 - 5 ms - contraction effect;
 - between 40 - 80 Hz - tetanizing currents used for therapeutic purposes.

Application technique:

- * bipolar technique: - electrodes of the size chosen depending on the size of the treated region are placed at the level of muscle insertions or on the muscle-tendon transition areas,
- * the intensity of the current must be chosen in such a way as to produce obvious and effective muscle contractions for the intended purpose, but without overstraining the muscle
- * the negative electrode is placed on the affected muscle at the level of the neuromotor plate and the positive electrode on an area proximal to it,
- * session duration: 20 - 30 minutes,
- * number of sessions: 8 - 12 per series.

Indications:

- * treatment of hypotonic abdominal muscles,
- * bladder and anal sphincter incontinence,
- * conditions after acute trauma of the locomotor system,
- * dysfunctional muscle groups in the vicinity of the denervated ones.

5.2.2. Totally denervated muscles therapy

There are 3 types of nerve damage:

- **Neuropraxia:** blockage in nerve conduction caused by a trauma that affected the myelin sheath; recovery occurs spontaneously in max. 8 weeks
- **Axonotmesis:** severe axonal injury with preservation of only the endoneurium and degeneration of the distal segment of the nerve (Wallerian degeneration); axon regeneration occurs by 1÷2 mm/day.
- **Neurotmesis:** very severe injury with total interruption of the axon; there is no regeneration without surgical suture.

Electrostimulation ensures preservation of the muscle's ability to respond to electrical stimuli, prevents muscle atrophy and keeps the neuromuscular plate in working order. Electrostimulation is not done if there is no chance of reinnervation. Denervated muscle is stimulated only with slope currents, because the accommodation capacity of the muscle has been lost by denervation and the muscle can also respond to lower current intensities. To establish the slope current parameters, the intensity-duration curve is used.

The use of slope currents will avoid excitation of normally innervated muscle fibers and sensory nerve fibers, so that denervated muscle fibers are the first to respond by contraction to stimulation.

- * totally denervated muscles respond selectively to stimulation by long-lasting exponential impulses, with a slow/very slow growth slope,

- * forms of currents used:

- progressive Lapicque currents with pulse durations between 100 - 1000 ms and frequencies between 1 - 10 pulses per sec.,

- currents with trapezoidal impulses - with stationary intensity,

- triangular currents with linear growth fronts.

- * the treatment must be instituted early, before the onset of muscular atrophic changes after the occurrence of the peripheral motor neuron injury and the appearance of its signs (max. 7-10 days),

- * signs of peripheral nerve injury are:

- reversal of the muscle response to electrical excitation (contraction at the positive pole),

- increased rheobase and chronaxia,

- accommodation coefficient α of the injured muscle close to 1 or below 1,

- the intensity-duration curve (I / T) moves to the right and up and is fragmented into steps (unevenly damaged neuromotor fiber units).

- * selective electrostimulation begins only after performing the electrodiagnosis by:

- the galvanic test of excitability,

- faradic excitability test,

- the I / T curve method - the most effective.

The technique of applying the I / T curve method:

This graph is used for diagnostic purposes to:

- determine the severity of the denervation;
- establishing stimulation parameters.

The graph establishes the relationship between the amplitude and the duration of the impulse that produces a minimum contraction of the muscle; it is done with triangular then rectangular impulses. The curve with triangular impulses is for the denervated fibers and the one with rectangular impulses for the ones that remain worthy.

* electrodes of equal size are placed at the ends of the muscle (their size adapts to the size of the muscle),

* the cathode is placed distally when there is no paradoxical response (if yes, reverse the cathode with the anode),

* the obtained data are shown in a graph with logarithmic scales: on the ordinate is the intensity (I) of the current in milliamps and on the abscissa is the time (T) expressed in milliseconds,

* the rectangular pulse shape is selected as a sequence of pulses; pulse duration of 1000 ms. and the pause between 2000 and 3000 ms,

* increase the intensity of the current until the minimum contraction (REOBASE) is obtained, which is noted in the graph,

* shorten the duration of the pulse, measuring each time the intensity of the current that produces minimum contraction, the values are entered in the graph.

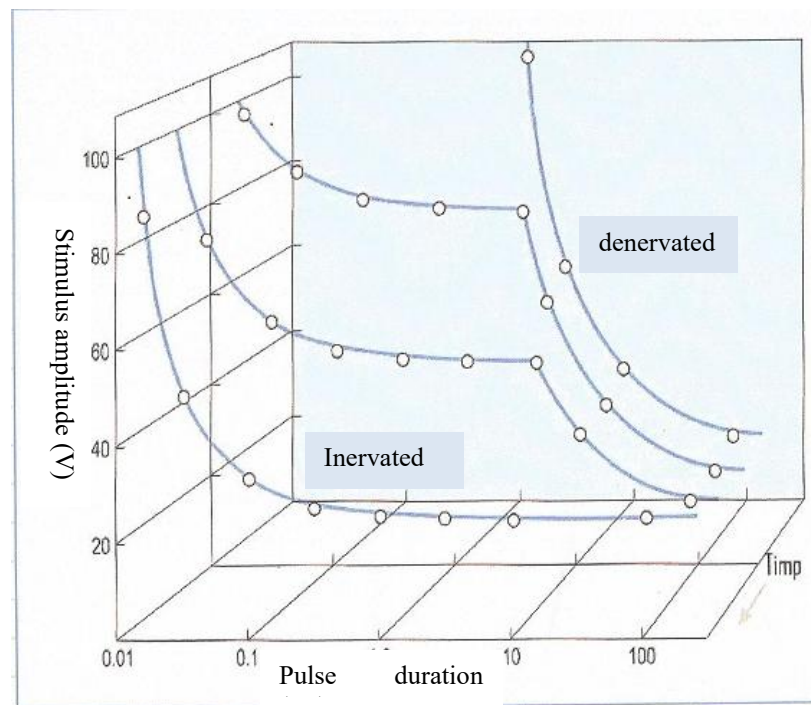


Fig.17. Intensity/duration curve for determining the degree of denervation

* at a certain duration of the impulse, in order to obtain the minimum contraction, an intensity greater than the rheobase is required; this time = USEFUL TIME,

* CRONAXIA is determined (the duration of the rectangular current pulse with an amplitude equal to twice the rheobase that produces minimum contraction), in two ways:

- by drawing on the graph a line parallel to the abscissa at the current value that represents double the rheobase and from the point of intersection of this line with the I / T curve, a perpendicular is drawn to the time axis,

- by direct determination on the patient.

The CIT curve (triangular impulse current) is raised, the duration of the growth front being practically zero,

* the accommodation coefficient denoted by α = the ratio between the intensity of the triangular current lasting 1000 ms is determined. and that of the rectangular current with the same duration, for the values that produce minimal contractions,

* in patients who have a layer of cellulo-adipose tissue, it is recommended to palpate to detect muscle contraction,

* to optimize the chosen parameters, it is recommended to determine the CID curve (rectangular impulse current) for the corresponding healthy muscle of the symmetrical limb.

It is established on the basis of the curve with rectangular impulses:

- **R** – rheobase = the amplitude of a rectangular pulse of infinite duration that produces a perceptible muscle contraction (mA)
- **C** – chronaxia = the duration of the rectangular pulse with an amplitude equal to double the rheobase, which produces a minimal contraction; $C = 0.1 \div 1 \text{ ms}$
- **TU** – useful time = the minimum time required for a rectangular impulse to produce a perceptible contraction, having an amplitude equal to double the rheobase; for healthy muscles $TU \approx 10 \mu\text{s}$.

Based on the curve with triangular impulses, the accommodation threshold is established, which represents the intensity of a triangular impulse with infinite duration that produces a minimum contraction; its value is $500 \div 1000$ ms. Based on these determinations, the accommodation coefficient α can be found.

α = sedation threshold/ rheobase, i.e

α = current intensity with a duration of 1000 ms/ rectangular current intensity with a duration of 1000 ms.

Where:

Normal α is between 2 and 6.

$\alpha = 1 \div 2$ partial denervation;

$\alpha < 1$ total denervation.

For totally denervated muscles, the curve is shifted far to the right. As reinnervation progresses, the curve shifts to the left. Making the intensity-duration graph can be repeated every 2-3 weeks to follow the reinnervation process. Electrostimulation does not prevent nerve degeneration or accelerate reinnervation. The duration of the triangular pulse to be used for electrostimulation is at the lowest point of the intensity-duration curve with triangular pulses. This is usually between $100 \div 1000$ ms.

The electrostimulation lasts until muscle fatigue is reached. The pause between contractions is at least $3 \div 4$ times longer than the pulse duration.

Ways to achieve electrostimulation of denervated muscles

After determining the duration of the impulse and its intensity in the electrodiagnosis (intensity-duration curve), we proceed to the actual stimulation.

Bipolar technique:

- the electrodes are placed at the ends of the affected muscle, usually with the (+) pole proximal and the (-) pole distal, with which the stimulation begins, on the tenomuscular junction.
- the denervated muscle no longer has a motor point from a functional point of view.

Monopolar technique:

- the negative electrode (-) is placed on the motor point of the affected muscle and the positive (+), regardless, on the proximal end of the muscle.

During electrostimulation:

- The patient concentrates on the treatment, imagining the movement to preserve the cortical image of the movement;
- The patient's posture must be adequate to relieve the respective limb from the force of gravity;
- The denervated muscle can be prepared for the electrostimulation session by local application of heat, massage or galvanic current.

The duration of the session is short and directly determined by the number of excitations applied.

About 15÷20 stimulations are done per session, in daily sessions. Stimulation is continued until reinnervation, with periodic reassessment. The muscle must be brought to strength 2.

The rhythm: 4 sessions per day at intervals of 15 - 30 min., to avoid muscle fatigue.

Frequency: daily, 7 - 10 - 14 days of treatment are recommended.

Electrostimulators can be

- portable: easier to handle, cheaper, safer (since the maximum intensity of the produced current is limited for security reasons)
- fixed: offers a wider palette of electrostimulation possibilities (types of current); produce currents with parameters that respond to any type of electrostimulation.

Devices that work with constant voltage are considered safer than those with constant current. The therapist will test the current first on himself before using it on the patient.

Types of electrodes:

- self-adhesive
- metal plates (lead)
- electrically conductive rubber

The electrodes are applied to the skin by means of an electrically conductive coupling medium which can be:

- gel (self-adhesive electrodes - disposable);
- moistened textile material;
- moistened sponge.

Electrodes must be cleaned and disinfected after each use; otherwise they can spread infections from one patient to another. The electroconductive gel contains: water, salts (NaCl, KCl), a surfactant material and bactericidal and fungicidal substances.

The size of the electrodes

They are chosen according to the purpose of the electrical treatment and the size of the area to be treated. Large electrodes allow working with lower current densities:

$$\text{Current density} = I (\text{Intensity}) / S (\text{Area}) = \text{mA/cm}^2$$

If the electrodes are of different sizes, the smaller electrode has a higher current density and is the "active electrode". The larger electrode is the "indifferent electrode". The smaller electrode allows the current to be "concentrated".

Placement of electrodes

In order to stimulate the normally innervated muscles, the "active" electrode is placed on the motor point of the muscle (the point where a muscle contraction with the greatest possible force can be obtained or on the path of the motor nerve).

MONOPOLAR STIMULATION

A very small (active) electrode is used and an indifferent (large) electrode is placed outside the area to be stimulated. It is used when stimulating smaller muscles (eg facial muscles).

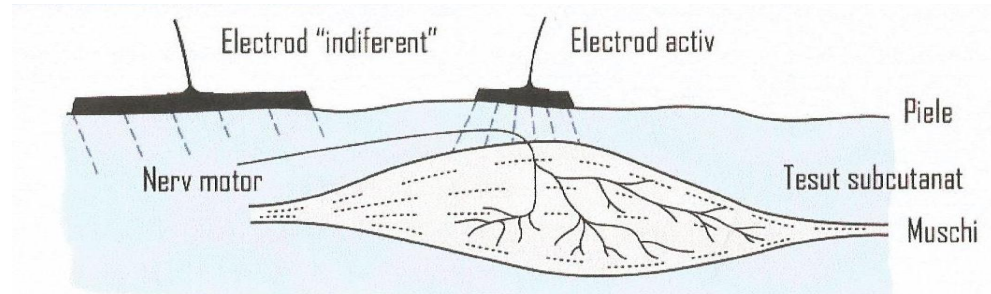


Fig.18. Unipolar electrode placement technique for muscle stimulation

BIPOLAR STIMULATION

Se folosesc doi electrozi de mărimi egale, plasați la capetele mușchiului sau grupului de mușchi de stimulat.

Această tehnică bipolară se folosește pentru stimularea musculaturii denervate, pentru că se vor stimula direct fibrele musculare.

Pentru tratamentele electrice de combatere a durerii se folosește tehnica bipolară, cu electrozi mai mari, ce asigură un impuls senzorial crescut și o stimulare motorie mai redusă. Un electrod poate fi înlocuit de 2 electrozi bifurcați, cu o suprafață egală cu cea a electrodului înlocuit.

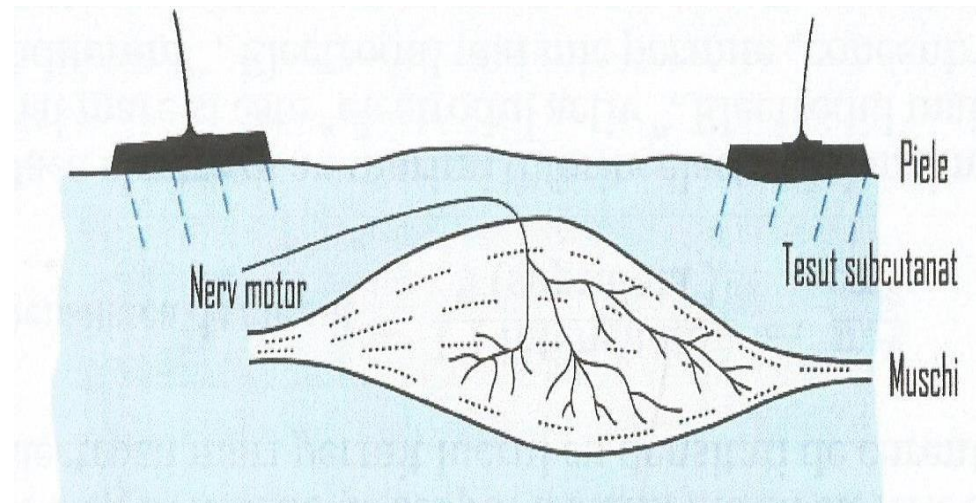


Fig.19. Tehnica bipolară de plasare a electrozilor pentru stimulare musculară

Transmiterea curentului se poate face și prin intermediul apei. În acest caz, densitatea poate produce arsuri electrice foarte reduse.

Principles and conditions

- * the patient must concentrate on the treatment, watch the movement, give the command of the voluntary movement by himself,
- * the patient seated in an appropriate posture in a plane free from the influence of gravity,
- * the treated segment must have a normal neighboring joint,
- * before the session, a local heating procedure, massage,
- * after introducing the physiotherapy sessions, you can continue with the selective stimulation of the affected Muscles

5.2.3. Spastic muscle therapy

- * consists of applying two separate but synchronized excitation circuits, each with two electrodes,
- * antagonistic muscle groups are stimulated, with increasing intensity until the appearance of strong muscle contractions (seizures),
- * principle of action:
 - by inhibiting the motoneurons of the spastic muscles, a relaxation effect is induced targeting the treated spastic muscles,
 - the relaxing effect of the spastic muscles is maintained for 24 - 48 hours at the beginning, then lasting effects are reached (3 - 4 weeks).

Practice

- * durata impulsurilor: între 0,1 - 0,5 ms.,
- * frecvența impulsurilor:
 - aproximativ 1 Hz (perioada corespunzătoare 1000 ms) pentru tratamente aplicate pe membrul superior,
 - 0,6 - 0,8 Hz (perioada corespunzătoare 1660 - 1250 ms.) pentru tratamente aplicate pe membrul inferior.

- * pulse duration: between 0.1 - 0.5 ms.,
- * pulse frequency:
 - approximately 1 Hz (corresponding period 1000 ms) for treatments applied to the upper limb,
 - 0.6 - 0.8 Hz (corresponding period 1660 - 1250 ms.) for treatments applied to the lower limb.
- * the delay time between the pulses of the two circuits between 80 - 300 ms.,
- * current intensity - chosen so as to produce a strong muscle contraction without unpleasant skin sensation
- * treatment duration:
 - for a segmental positioning 10 min.,
 - for successive positionings maximum 40 - 50 min.

frequency of sessions: daily in the initial stage of treatment,

- * pace of sessions: 12 - 18 sessions,
- * small plate electrodes are used, applied bipolarly above the excitation points of the muscle, on a layer hydrophilic, well-wetted intermediate or electrode paste; it is fixed with elastic bands.

Indications:

- * spasticity in paresis, paralysis of cerebral origin,
- * spasticity following birth trauma,
- * traumatic brain and spinal cord injuries (with the exception of spastic paralysis),
- * spastic paresis in multiple sclerosis,
- * spastic hemiparesis after stroke,
- * Parkinson's disease

Contraindications:

- * amyotrophic lateral sclerosis,
- * advanced diffuse sclerosis.

5.2.4. Stimulation of smooth muscle contraction

Smooth muscle has special physiological features, namely:

- has no accommodation capacity (negligible accommodation)
- the chronaxia is very long, hundreds of ms.
- smooth muscles have a high summation capacity of applied electrical stimuli.

Practice

The smooth muscle is stimulated with exponential or triangular currents (single impulses or series of impulses), with a very long slope of increasing impulse intensity (500÷800 ms), with a long pause between impulses (one impulse every 1-4 sec.). The intensity of the stimulation current is usually 20÷30 mA.

* flat electrodes of equal size (200 - 400 cm²) are used, which are applied to the area to be treated, usually on the abdomen

* in chronic atonic constipation - the electrodes are placed on the flanks of the abdomen

* in the atonic bladder - the (-) pole is placed above the pubic symphysis and the (+) in the sacral area.

* pulse duration:

- 400 - 500 ms. in atonic constipation

- 200 ms. in bladder and uterine atony.

* pause duration 1000 - 3000 ms,

* current intensity: 20 - 30 mA

* session duration:

- 10 - 15 min. in bladder atony,

- 30 - 50 min. in constipation,

- 30 - 60 min. in weak contractions at birth

* the rhythm of the sessions: daily, then they become less frequent every 2-3 days

* a large number of sessions (20÷25) is required.

5.3. Diadynamic currents

5.3.1. Definition

Diadynamic currents were discovered by a French dentist, Pierre D. Bernard, in 1929. Diadynamic current is a low frequency current, which is part of the "conventional" low frequency analgesic methods. It can be in the form of a half-wave or full-wave sinusoidal current, with a frequency between 50-100 Hz. The diadynamic current is actually an application of two components of the electric current - galvanic and pulsating. One side represents the base and the other the dose. Bernard empirically identified the effects of diadynamic current, so that, at a frequency of 50 Hz, cells are excited, and at 100 Hz they are inhibited. Diadynamic currents start from the frequency of 50 Hz, pulse duration of 10 msec, providing 100 stimuli/sec.

5.3.2. Characteristics

Diadynamic currents indicate the simultaneous action of two forces. One is the galvanic current and usually represents the base. This is combined with a pulsating component, called dose (fig. 12). The galvanic component subjectively improves the current tolerance, and therefore improves the effective current penetration depth. In older devices the setting was set between 1 – 3 mA. Today, it is expressed as a percentage of absolute intensity. That is why it is important to write down the absolute intensity from the documentation for the use of the device and based on it to determine the percentage of the galvanic part, which must be between 1 - 3 mA.

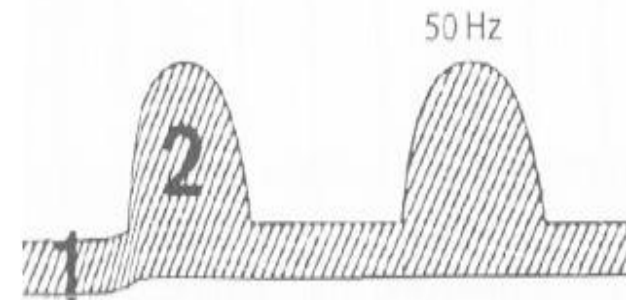


Fig. 20. Galvanic component (1) and pulsed (2) of diadunamic current¹

¹ source: poděbradský, & poděbradská,

The pulsating component is represented by fixed single-phase or fixed two-phase alternating current (DF, $f = 50$ Hz, pulse duration 10 ms, intrapulse interval duration 10 ms). By modulating the amplitude and frequency, other combinations of the diadynamic current can be obtained. By combining frequency and current strength, and adding constant (galvanic) current, several modulations can be obtained.

Modulation with frequencies between 1 – 100 Hz has a good analgesic and VSNS¹ blocking effect. It is used in the treatment of algic conditions that affect the balance of the vegetative system.

Modulation with frequencies between 2 - 50 Hz has a strong analgesic and sympathetic blocking effect better than modulation 1. It affects the tone of connective tissues, which is very important in the post-traumatic healing process.

Modulation 3 – is a combination of modulations 1 and 2. It has a strong effect on edema and hematomas, reduces the tone of striated muscle fibers and removes pain.

Modulation 4 – is a combination of modulation 1 to which weak galvanic impulses are added, and modulation 2. It has a strong and long-lasting analgesic effect, the effect being called electroanalgesia.

The diadynamic current is used in the treatment of painful syndromes and in extra-articular rheumatism. Some modulations can be combined (e.g. 1 and 4) for a stronger effect. It is introduced into the human body through simple electrodes or vacuum.

There are several methods of application:

- transregional application (to the painful place on the affected nerve),
- paravertebral or segmental
- vasotropic.

The applications last 4 - 6 minutes with the poles reversed halfway through the application. If there are multiple application areas, the optimal application period is 15-20 minutes. Diadynamic current applications are daily, and in case of very strong pain, even twice a day. Treatment usually lasts 10-20 days.

¹ vegetative sympathetic nervous system

5.3.3. Classical forms of diadynamic currents

* **fixed diphase (DF)** – alternating current of 100 Hz, analgesic effect, produces a tingling sensation and muscle contraction at high intensity (it is also used in circulatory disorders).

* **single-phase fixed (MF)** - alternating current of 50 Hz, produces a sensation of strong penetration of vibrating waves and muscle contraction at much lower intensities than fixed two-phase current; excitatory effect, increasing muscle tone, vasoconstrictor action

* **long period (LP)** – low frequency currents with equal phases of DF and MF, analgesic, muscle relaxant effect.

* **short period (SP)** – combination of 10 sec. MF followed by 5 sec. DF; excitatory, tonic, resorptive effect, long-lasting analgesic effect.

* **syncopated rhythm (RS)** – 1 sec MF followed by 1 sec. rest; pronounced excitomotor effect (muscle stimulation) and tests nervous excitability.

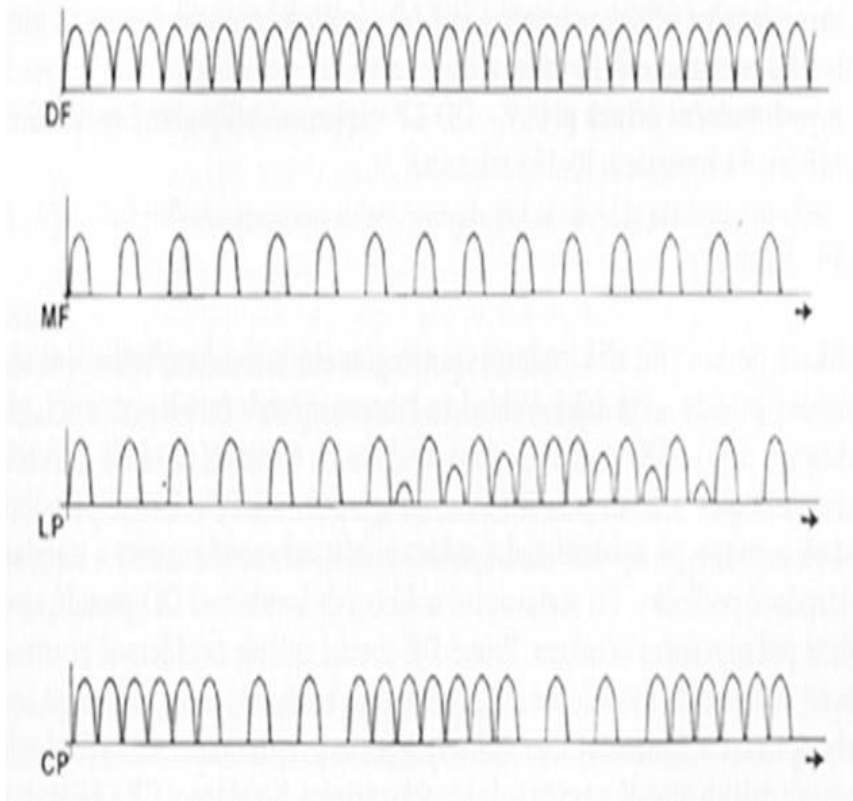


Fig.21. Classical forms of dyadinamic currents¹
*

¹ source: <http://www.fsps.muni.cz/impact/physical-therapy-3/diodynamic-currents>

5.3.4. Physiological effects

- * analgesic (increases the sensory stimulation threshold)
- * stimulation of muscle fibers (diadynamic current stimulates muscle fibers causing muscle contraction).
- * vasodilatation and hyperemia (release of histamine in the tissues – the same effect can occur reflexively, in the deeper structures)
 - * food,
 - * resorptive (SP and LP increase blood flow in muscles and reduce edema)
 - * dynamogen (stimulation of the vibratory sense that masks the sensation of pain - according to the gate theory of pain control)

These are determined by the level of intensity, the form of the diadynamic current and the method of applying the electrodes, as well as by the particularities of the individual reaction and the body's adaptation to the current.

5.3.5. Application modalities

They are polar currents, so their application can be a bit unpleasant, with the patient feeling a strong stinging or numbness sensation. Diadynamic currents are applied for short periods of time: 4÷6 min (max. 10 min).

To combat accommodation the polarity is reversed or several types of diadynamic currents are used successively.

Diadynamic currents can have an excitatory effect, causing muscle contractions (especially MF and RS).

Because increased intensities and longer durations of excitomotor treatment are required, diadynamic currents are not used for this purpose.

The active electrode is the (-) pole. They can be applied longitudinally or transversely on the area to be treated. Paravertebral or nodal applications can also be made; if the electrodes are at a great distance from each other, no noticeable therapeutic effects are obtained. (Drăgan Adriana, 2007)

In therapeutic applications, the following will be observed:

- ❖ flat electrodes are used;
- ❖ protective or reversible polarity solutions (marked with x) are used every 6 minutes
- ❖ the combination of the pulsating components and their length is determined
- ❖ the subjective intensity is determined according to the desired effect
- ❖ the application time will be 6-12 minutes depending on the type of combination chosen;
- ❖ the treatment is applied daily, depending on the desired effect

Applications can be as follows:

- * applications on circumscribed painful points: small, round electrodes, equal in size; the "-" pole on the painful place, the "+" pole about 2 - 3 cm away,
- * transverse applications: electrodes of appropriate and equal size (for large joints), placed on either side of the painful area,
- * longitudinal applications: along a peripheral nerve, the larger "+" electrode is usually placed proximally in the emergence area and the smaller "-" one, distal to the affected area,
- * paravertebral applications: flat electrodes of adapted size, the cathode on the painful site or along the spine with the proximal anode and the distal anode,
- * gangliotropic applications: small, round electrodes, the cathode on the area of the respective ganglia and the anode at 2 - 3 cm. distance.

Division. In addition to the type of pulsating components of the diadynamic current mentioned above, AMOS currents can also be included here. They use pulsating components in longitudinal application, in the treatment of ischemia of the lower limb in stage IIb according to Fontaine, characterized by the appearance of claudication that varies from moderate to severe, over a distance of less than 200m. The duration of Amos current applications varies between 20 and 25 minutes without polarity reversal, and therefore it is necessary to use protective solutions for individual electrodes. The 20 x 20 cm anode is placed transversely in the L2-S1 area and a smaller, flat cathode is placed in the distal third of the calf. The procedure is applied 3 times a week for 3 weeks. (Poděbradský, J., & Poděbradská, R., 2009)

5.3.6. Indications of diadynamic currents

* musculoskeletal system:

- post-traumatic conditions: - contusions, sprains, dislocations.
- muscle strains,
- joint stiffness,
- rheumatic conditions: - reactivated arthrosis, arthritis, myalgia, articular manifestations.

* peripheral circulatory disorders: acrocyanosis, varicose disease, conditions after frostbite or burns, obliterating peripheral arteriopathy.

* segmental applications targeting neuro-reflex areas in suffering with neurovegetative pathogenesis of the stomach, gallbladder, colon, bronchial asthma.

5.3.7. Contraindications

- definite or suspected fractures
- acute inflammations
- active tuberculosis of bones, joints or other organs¹
- malignant diseases
- diseases causing cachexia²
- cardiac decompensation
- hemorrhagic conditions
- metallic implants (after injuries, endoprostheses, osteosynthesis materials, etc.)

¹ Tuberculosis is a contagious disease that mainly affects the lungs, but can spread to the spine or other bones. Symptoms of bone tuberculosis include back pain, fever, and extreme fatigue.

² Cachexia is a syndrome or group of symptoms characterized by a progressive weakening of the body, up to emaciation (very pronounced weakening, which occurs after a long-term illness). Patients suffering from cachexia have a lack of appetite, pale, fine, dry skin, reduced axillary and pubic hair to the point of disappearance, brittle nails, sparse, thin, falling out hair on the head, bradycardia, hypotension, anemia. From a neuropsychic point of view, patients with cachexia are asthenic, with slow speech, anxious, depressed, melancholic.

5.3.8. Practice

- * the size and shape of the electrodes are chosen depending on the areas treated and the locations, positioning method and polarity depending on the intended purpose,
- * positioning of the patient - depending on the region to be treated - on beds or wooden chairs,
- * the electrodes are applied using hydrophilic protective covers, well moistened and fixed with elastic bands or sandbags,
- * the current intensity is regulated by progressive increase to a dose corresponding to the intended effect, without reaching the threshold of painful sensitivity,
- * the intensity will be increased over time to maintain the sensation of painless vibration,
- * the duration of the session in relation to the therapeutic goal pursued, will be short (4 - 8 min. or even less),
- * the rhythm of the sessions established depending on the stage of the condition being treated: acute stages 2 times a day or once a day,
- * the number of sessions: - analgesic purpose 6 - 10 sessions,
- dynamogenic or hyperemic purpose, over 10 sessions, depending on the case

Dosage:

- * *Intensity*: will be increased gradually, until a well-defined sensation of vibration or tingling appears.
- * *Duration*: no more than 12 minutes; each type of application maximum 3 minutes.
- * *Frequency*: Daily or every other day, up to 12 sessions.
- * *DF*: used in the initial treatment, before applying other types of current. The patient feels a tingling sensation, which decreases in intensity after a short time.
 - *MF*: The patient feels a strong vibration sensation for a longer time than the sensation produced by DF. It is used in the treatment of pain without muscle spasm.
 - *CP*: In the DF phase the patient feels a slight tremor and in the MF phase he feels constant and strong vibrations. They are rhythmic contractions used in the treatment of post-traumatic pain.
 - *LP*: It has a long-lasting analgesic effect. It is used in combination with CP in the treatment of neuralgia.
 - *RS*: It can be used for faradic muscle stimulation and as a test for the excitability of motor nerves.

5.4. Träbert current

5.4.1. Definition

Träbert uses the term '2-5 current' to refer to a direct current with a rectangular pulse, a phase duration of 2 ms and an interval of 5 ms. This type of current is known in the literature as 'Ultra-Reiz' current.

The frequency of the current is approx. 143 Hz (143 cycles/sec.). The treatment duration is 10 - 15 min.

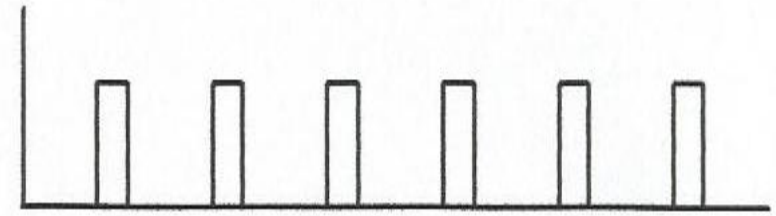


Fig.22. Träbert current – 143 Hz

This type of current is suitable for selective stimulation of thick fibers. Its configuration is very simple. Träbert did not provide any explanation for the choice of these parameters. However, many therapists have adopted this therapy according to Träbert, and it is still successfully applied.

A remarkable effect of applying this current is the reduction of pain, which can occur from the first treatment and which can last for several hours.

5.4.2. Modalitatea de aplicare a curentului Träbert

Träbert describes four typical electrode locations that are well suited for segmental applications.

The polarity depends on the area of choice. For example, the location of the electrodes for headache and neck pain is the same. In the treatment of headache, the negative electrode is positioned caudal to the positive electrode, while in the treatment of neck pain radiating to the arm, the negative electrode is positioned proximal to the positive electrode.

For example, the location of IV electrodes is done for the treatment of intermittent claudication. If the condition is bilateral, the negative electrode can be divided and positioned in the gluteal region.

The active electrode is the (-) and is usually applied to the painful site and the (+) electrode approximately 2 – 3 cm. away

After the therapy is applied, the phenomenon of accommodation occurs and the patient no longer feels the sensation of current – thus the amplitude is increased progressively, several times during the therapy, to a tolerable level of 70 – 80 mA. The amplitude is increased until the appearance of muscle contraction. This should be palpable or just visible. Contractions contribute to improving blood perfusion at the muscle level (muscle pump mechanism).

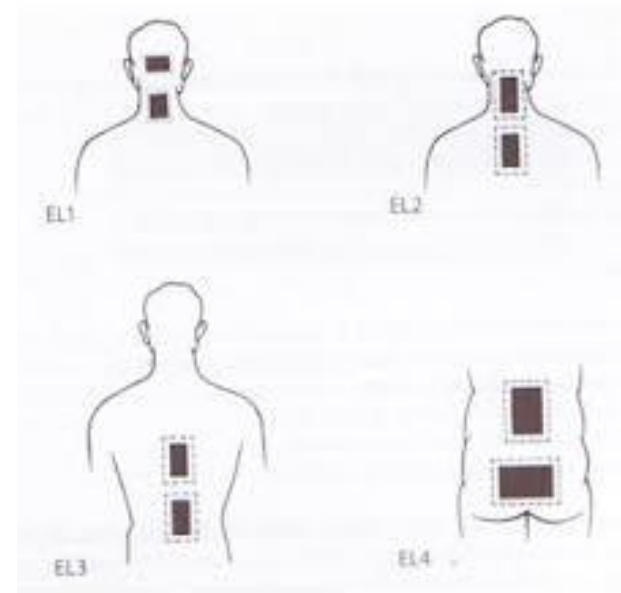


Fig.23. Aplicații ale curentului Träbert (R.V. Den Axel, RHJ Luykx, 2005)

In practice, this means that the current amplitude is increased at intervals of 1 minute. The tolerance limit is generally reached after 5 - 7 minutes, after which the current amplitude is not increased any further. In some cases, the amplitude will reach 70-80 mA. The vast majority of patients tolerate the current well up to 10 mA, after which the unpleasant sensation appears.

Although the direct value is relatively low, the increase in amplitude makes it necessary to use 1 cm thick, well-moistened sponges. If necessary, they will be further moistened during the treatment.

The electrodes must be fixed very well with Velcro strips. When muscle contraction occurs, fixing the electrodes with sandbags is not always sufficient.

In the specialized literature, a treatment duration of 15 minutes is specified. (R.V. Den Axel, RHJ Luykx, 2005) Träbert currents are used in the subacute period.

5.4.3. Effects of Träbert current

These currents have an effect

- predominantly analgesic (it is the most analgesic form of current)
- hyperemic (improves peripheral circulation in the application area)
- of decreasing muscle tone

5.4.4. Indications

- pain syndromes of known etiology
- degenerative diseases of the spine (vertebral arthrosis radiculopathy, spondylosis)
- muscle pain
- degenerative joint diseases
- ankylosing spondylitis
- non-articular rheumatism: epicondylitis, coxofemoral, scapulohumeral periarthritis
- post-traumatic conditions
- neuralgia
- peripheral circulatory disorders

5.4.5. Contraindicații

- applications on the anterior neck area
- transthoracic applications
- skin lesions
- patients with pacemakers or metal implants
- pregnant uterus
- malignant tumors

5.5. Risks, contraindications and general precautions in applications of low-frequency currents

- * do not apply to the precordial region,
- * abrasions, wounds, dermatological lesions,
- * allergies to various substances detected in the anamnesis,
- * verification of the integrity of the electrodes,
- * compliance with the conditions for use of the hydrophilic protective material: appropriate thickness; to exceed the edges of the metallic electrode; to be well moistened and evenly soaked with water or medicinal solution,
- * avoiding regions where metal osteosynthesis parts, endoprostheses, IUDs are incorporated,
- * do not apply in local hemorrhagic conditions, superficial and deep venous thrombosis, during menstruation and a pregnant uterus,
- * areas with loss of thermal sensitivity are avoided.

6. MEDIUM FREQUENCY ELECTRIC CURRENT. INTERFERENTIAL THERAPY

6.1. General notions

Interferential therapy was developed in Australia in the 1940s and became a very popular treatment modality in America, because it treats deep tissues. In Europe, more precisely in Vienna, Dr. Nemec introduced these currents in the early 1950s. He wanted to solve the problem of discomfort caused by low-frequency currents and at the same time maintain their therapeutic effect. Since at that time few powerful analgesic drugs appeared, and electrotherapy was considered only a palliative form of treatment, this form of currents fell out of the attention of therapists until the late 1960s and 1970s, when Melzak/Wall demonstrated that pain can be blocked by stimulating primary neuronal afferents. Interferential therapy is one of the methods that can be applied to almost any area of the body, to treat acute and chronic conditions by changing the frequency and intensity used.

		
Fixed device of interferential therapy	Mobile device of interferential therapy	Multifunctional device including also interferential therapy

According to Gildemeister and Weyss, medium-frequency currents are currents with frequencies between 1000 – 100,000 Hz. The basic principle in interferential therapy is to utilize significant physiological effects of

nerve stimulation with low frequencies, without associating the somewhat painful and unpleasant side effects characteristic of low-frequency current therapy.

Recently, numerous portable interferential current generating devices have become available on the market. Despite their size, they are perfectly capable of performing interferential therapy, although some have limited functionality, reducing the therapist's ability to set all parameters. Most devices include all interferential modes.

Interferential therapy has been used for many years (Pope et al, 1995 and more recently Shah and Farrow, 2007).

6.2. Principles

In order to produce the effects of low-frequency current at a sufficient intensity and adequate tissue penetration, the patient may experience considerable discomfort in the superficial tissues (skin).

This is due to the impedance of the skin, which is inversely proportional to the stimulation frequency. In other words, the lower the stimulation frequency, the greater the impedance to the passage of the current and consequently the greater the discomfort experienced by the patient, as the current is pushed through the tissues against this barrier. The impedance of the skin at 50Hz is approximately 3200, while at 4000Hz this is reduced to approximately 40. Applying a high frequency results in the current passing more easily through the skin, requiring a smaller electrical impulse to reach the deeper tissues. Consequently, it will create less discomfort.

The effects of stimulating tissues with medium-frequency currents (medium frequency in medical terms is between 1KHz-100KHz) are still being studied.

Interferential therapy uses two medium-frequency currents, which simultaneously penetrate the tissues and which are set so that they cross, hence the name of this type of electrotherapy.

This interaction gives rise to an interferential current that has the characteristics of a low-frequency current (in other words, the interference of the two currents mimics low-frequency stimulation). The exact frequency of the resultant of the interaction of the two medium-frequency currents can be controlled by the input frequencies. For

example, one current has 4,000 Hz and the other has 3,900 Hz; in this case the resultant frequency is 100 Hz (the difference between the frequencies of the two medium-frequency currents).

Prin manipularea atentă a curenților se poate obține orice frecvență ce se dorește a fi folosită în clinic.

By careful manipulation of the currents, any frequency desired for clinical use can be obtained.

Modern devices offer frequencies between 1 and 150 Hz, some even up to 250 Hz or more, frequencies that are no longer set manually, but are selected directly from the device. The amplitude of the low-frequency interferential current is, in theory, approximately equivalent to the sum of the amplitude of the inputs.

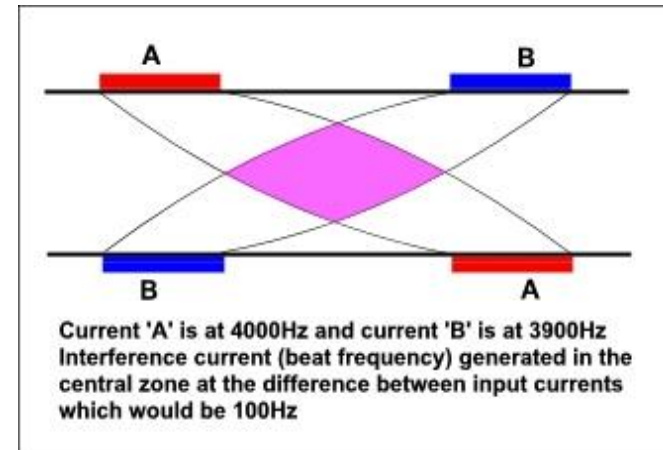


Fig.24. Interferential current

Interferential current treatment can be performed using two electrodes (the interference of medium-frequency currents is premodulated by the device) or using 4 electrodes (the interference of medium-frequency currents is performed directly in the tissues). There are no known differences between the physiological effects obtained by applying interferential therapy using the 2-electrode system compared to the 4-electrode system. Regardless of how it is generated, the effects of the treatment are given by low-frequency stimulation, the peripheral nerves being the first involved.

Low-frequency nerve stimulation is effective from a physiological point of view, this fact being the key to interferential current therapy.

6.3. Frequency modulation (gradual change of frequency)

Nerves adapt to a constant signal, and therefore gradual change of frequency is often used to solve this problem. The principle of using modulation is that the device is set to automatically change the stimulation frequency, using amplitudes either preset or set by the therapist.

The amplitude of the modulation must be consistent with the desired therapeutic effect.¹ It has been repeatedly shown that high amplitudes are ineffective. The modulation pattern significantly changes the stimulation perceived by the patient. In general, the transition from the lower to the upper frequency limit is achieved in 6 seconds or 3 seconds.

The maximum therapeutic effects are located at the crossover level of the two medium-frequency sources, of constant amplitudes but with different frequency - 100 Hz. The variation of the amplitude between 1 - 100 Hz., of the frequency difference between the two medium frequency circuits, generates the medium frequency effects.

Within this frequency variation, it is accepted that:

1. frequencies up to 10 Hz are excitatory
2. frequencies between 10 - 50 Hz are decontracting
3. frequencies between 80 - 100 Hz are analgesic.
4. frequencies between 1-30Hz reduce edema - cause electroporation²; increase lymphatic and venous flow, as well as tissue and vessel tone, favoring the reduction of edema
5. frequencies between 1-10Hz cause vasodilation with a strong pump effect, which will stimulate the physiological mechanisms of exudate absorption.

¹ Therapists should be aware that some devices set the upper and lower frequency limits (e.g. 10 and 25 Hz), while others set the lower limit and how much needs to be added to the base frequency to reach the upper limit (e.g. 10 and 15 Hz).

² increases the permeability of the cell membrane which allows the movement of ions in and out of the cell

Several modulation patterns can be achieved. For example, the following diagram shows three examples of a modulation with a range from 90 to 130 Hz, namely:

- **triangular pattern**, in which all frequencies between the set upper and lower limits are delivered in equal proportion.

- **rectangular pattern**, which determines a different stimulation, in which the lower and upper frequency limits are set, and the device directly changes only these two frequencies, without a graduated intervention.

There is a clear difference between these examples, even though the same frequencies are set.

One will allow the application of a full range of amplitudes between the set limits, and the other will allow suddenly switching from one frequency to another.

There are numerous other variations, and the **trapezoidal pattern** is one of them, being effectively a combination of the first two. The only modulation pattern for which there is clinical evidence is the triangular pattern. The use of the others is safe, but their clinical effectiveness is not yet fully known.

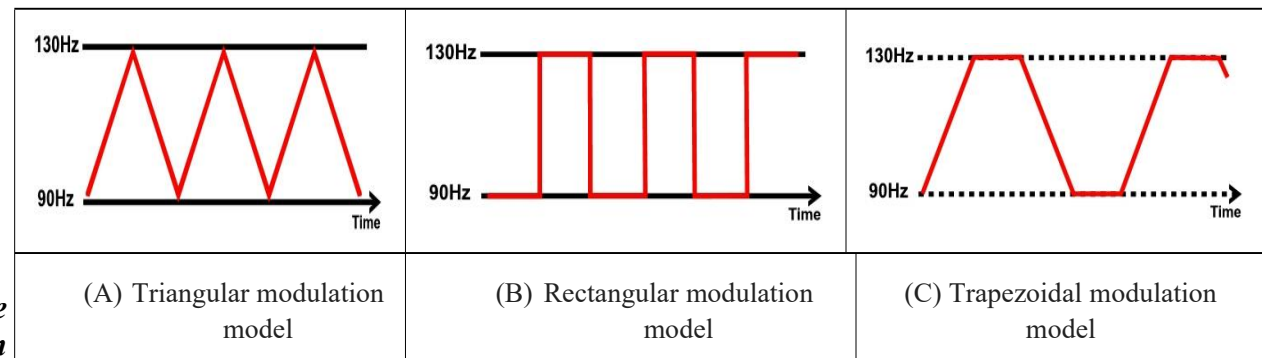


Fig.25. Types of interference current frequency modulation

6.4. Physiological effects

- * excitomotor,
- * vasodilator,
- * trophic,
- * resorptive,
- * decontracturant,
- * analgesic,
- * parasympathicotonic,
- * sympatholytic

NOTE. Interferential therapy is not effective in post-traumatic pain in acute stages. It is effective only in chronic pain, with or without edema!!!

6.5. Clinical applications

There are 4 main applications of interferential therapy:

- 1. Pain reduction**
- 2. Muscle stimulation**
- 3. Increased local blood flow**
- 4. Reduction of edema**

Added to these is the role of interferential therapy in stimulating healing or its specific applications, such as in urinary incontinence.

Interferential therapy acts mainly on excitable tissues (nerves), the strongest effect being the result of such direct stimulation (e.g. pain reduction and muscle stimulation). The other effects seem rather secondary to the first two discussed above.

Pain reduction: Electrical stimulation for pain reduction is widely used in the clinic, although there is little evidence of its effectiveness. One type of electrical stimulation may use high frequencies (90-130Hz) to stimulate the pain control gate mechanisms and thus mask painful symptoms. Another type of stimulation, low frequency currents (2-5Hz), may be used to activate opioid mechanisms, resulting in pain reduction. These two different modes of action can be explained physiologically and will have different latency periods with different duration of effect. It is possible that this pain reduction can be achieved by stimulating the reticular formation at frequencies of 10-25Hz or by blocking C-fiber transmission at >50Hz.

Neither of the latter two options has yet been clinically proven. A large number of studies demonstrate the effectiveness of interferential therapy in reducing pain (Hurley et al 2001, Johnson and Tabasam 2003, Samuel D., 1993, McManus et al 2006)

Muscle stimulation: Motor nerve stimulation can be performed at a wide variety of frequencies.

Low-frequency stimulation (1 Hz) will cause muscle spasms, while 50 HZ stimulation will cause tetanic contraction. Evidence-based evidence is not sufficient to support the strengthening (tonifying) effect of medium-frequency currents.

Muscle contraction induced by interferential currents is not more effective than that obtained by active exercise. However, there are circumstances in which assisted contraction is beneficial. For example, to assist a patient in appreciating the muscular work required, in patients who cannot generate a voluntary muscle contraction, or in the case of individuals for whom active exercise is difficult to perform.

The choice of treatment parameters will depend on the desired effect. The most effective range of interferential stimulation appears to be between 10 and 20 Hz, or even between 10 and 25 Hz. Stimulation below 10 Hz produces a series of coarse spasms, which may be effective, but this has not been clinically demonstrated. Stimulation at higher frequencies, around 20 – 25 Hz, may produce tetanic contractions, which may be considered beneficial in assisting the patient to appreciate the necessary muscular work.

Increased local blood flow: There is little scientific evidence in the literature to prove the direct effect of interferential current therapy on the modification of local blood flow. Noble et al. (2000) demonstrated the occurrence of vascular changes under the action of a medium-frequency current of 10-20 Hz, but failed to clearly identify the mechanisms of this change. The stimulation was performed through vacuum electrodes, the result being more likely to be due to the action of the vacuum and less to that of the interferential current. It is assumed that the effect of increasing local flow is due to muscle stimulation (muscle contraction with increased local metabolism and increased blood flow). The most effective frequency modulation for this purpose seems to be that of 10-20 or 10-25 Hz.

Edema reduction: Interferential therapy is effective in reducing tissue edema. The evidence is also limited in this case and the mechanisms by which this is possible are not known. The most plausible explanation would be that muscle contraction and changes in blood flow result in the reabsorption of fluid from the tissues.

The use of vacuum electrodes may be effective, although this has not yet been scientifically proven. If interferential therapy has the ability to influence edema, current scientific evidence and physiological knowledge suggest that a combination of pain reduction methods (allowing more movement) with muscle stimulation and increased local blood flow is effective in this regard.

Other clinical applications: In addition to the 4 major effects of interferential current therapy, there are also specific situations where it is suitable. And here we refer to electrostimulation as part of the management of urinary incontinence and pelvic muscle training (Parkkinen et al, 2004), constipation in children (Chase et al, 2005, Queralto et al 2013), fibromyalgia (Almedia et al, 2003; Raimundo et al, 2004) and trigger point intervention (Jenson et al, 2002). It has also been studied to stimulate the healing of some fractures, with mixed results. (e.g. Ganne, 1988)

6.5. Treatment parameters

Stimulation can be applied using plate electrodes covered with a spongy material (which, when impregnated with water, ensures better conductivity of the current). There is also the effective alternative of electroconductive gel.



Fig.26. a) Plate electrodes; b) Vacuum electrodes

The sponges should be wet over the entire surface to ensure even current distribution. Self-adhesive electrodes are also available. Vacuum electrode applications are used in applications on large areas of the body,

such as the shoulder, trunk, hip, knee. However, they do not seem to have a therapeutic advantage over plate electrodes (in other words, the vacuum component does not seem to have a measurable therapeutic effect).

Particular attention should be paid to the maintenance of the electrodes, hydrophilic materials and infectious risk factors (Lambert et al 2000). Regardless of the type of electrodes used, their positioning should ensure adequate coverage of the area to be stimulated. The use of large electrodes will minimize patient discomfort, while small, close-packed electrodes will increase the risk of superficial tissue irritation, possible skin lesions, and even burns.

Bipolar application (with 2 electrodes) is acceptable and there are no differences in the physiological effects generated by this type of application compared to the 4-electrode application. Recent studies support the benefit of applying 2 electrodes (Ozcan et al 2004).

The treatment period varies greatly depending on the usual clinical parameters used in chronic/acute conditions and the physiological effect sought. In acute conditions, and especially in exacerbations, short treatments of 5-10 minutes are sufficient to produce the effect. The time can be increased if the desired effects have not been obtained and if no other undesirable effects occur. There is no practical evidence that prohibits the progressive increase of the treatment time. In other circumstances, tissue stimulation for 20-30 minutes is necessary.

The following should be noted:

- Type of application: number and type of electrodes (2, 4 electrodes)
- Frequency applied
- Modulation frequency (if applicable)
- Current intensity (sensation perceived by the patient)
- Duration of the session and treatment.

6.6. Application methods

Treatment technique

- The patient is positioned comfortably, with the area to be treated exposed; the procedure, its duration and purpose are presented.

- The operation of the device is checked. The electrodes are chosen according to the size of the area to be treated.

There are electrodes:

- classic, made of electroconductive rubber or self-adhesive
- vacuum type: preferred in the case of interferential currents because they are easier to fix on the patient
- 4-pole pads; used to treat small anatomical areas (pain points, facial treatments)
- “glove” type electrodes.

They are used in dynamic applications with some types of devices. It is not necessary to increase the intensity during the therapy.

- The working parameters are set on the device:

- medium frequency amplitude 75÷150 Hz – analgesic effect
25÷50 Hz – excitatory effect

- Spectrum:

- a) a wide spectrum and low amplitude of medium frequency currents is used in chronic or subacute pathology; the patient feels a variety of sensations

- b) a narrow spectrum and high amplitude of medium frequency currents is used in acute pathology, in people more sensitive to the current

- The current intensity is set in collaboration with the patient; some devices have their own remote control with which the patient sets the intensity as desired

- Frequency:

- a) 2 kHz of interference currents produces a more pronounced motor effect; the current sensation felt is stronger; it is used when there is no pain and we only need an excitatory effect

- b) 4 kHz, it is used for analgesic effects.

- The duration of a treatment session varies between 10 and 30 min.

Treatment sessions are performed:

- daily or 2-3 times a day in acute conditions
- 2-3 times a week in chronic conditions
- daily in subacute conditions

* planar interference: - the interference current is obtained in the electrodes of the two sources, the electrodes being arranged in the sa

* spatial interference: - the interference current is obtained at the crossing of the direction of medium-frequency currents in which the electrodes are arranged in parallel planes.

* types of electrodes:

- **plate electrodes**: - they are flat electrodes, variable areas, arranged two by two, fixed by rubber bands, "hedgehog" bands.
- **special electrodes**: - point electrodes with a diameter of 4 mm, for small areas to be treated,
 - eye electrodes, mask type,
 - ring electrodes, thoracic,
 - palmar electrodes for large surfaces,
 - vacuum electrodes: perform a deep massage, enhancing the vasodilator, trophic, resorptive effects.

* frequency types:

- spectrum 0 - 100 Hz: for 15 s. the frequency difference between the two medium frequency currents is traversed ascending (0 -100 Hz) and descending (100 – 0 Hz).
- manual, with the variants:
 - **0 - 10 Hz.**, for 15 s, the respective frequency range is traversed ascending (0 - 10 Hz) and descending (10 - 0 Hz), within the amplitude difference between the two medium frequency current sources.

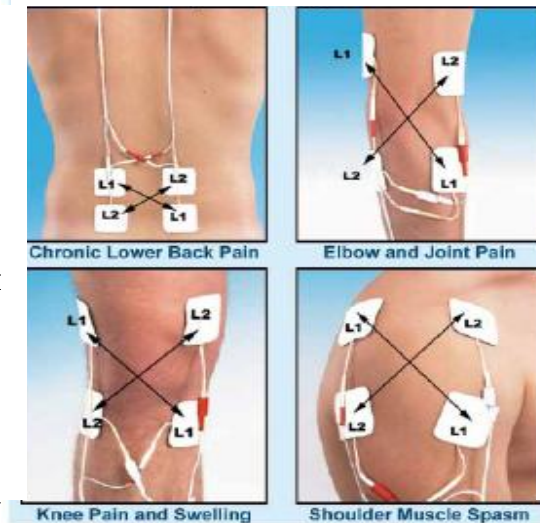


Fig.27. Plane interference

- **50 - 100 Hz:** for 15 s. the respective frequency range is traversed ascending (50 - 100 Hz) and descending (100 - 50 Hz).

- **90 - 100 Hz:** for 15 s, the respective frequency range is traversed ascending (90 - 100 Hz) and descending (100 - 90 Hz), within the amplitude difference between the two medium frequency current sources.

- * intensity of the medium frequency interferential current: - is established progressively, subjectively, until a tingling sensation; it is of the order of mA units.
- * duration of sessions: - varies depending on the condition to be treated,
 - in practice between 10' - 15' - 20'.
- * number of sessions: - varies depending on the condition to be treated,
 - in practice, between 6 - 16 sessions, 1 session per day.

6.7. Therapeutic indications

- * traumatology: contusions, sprains, dislocations, fractures, post-traumatic hematomas
- * rheumatology: arthritis, arthrosis, non-articular rheumatism (tendinitis, bursitis, enthesitis, fibromyalgia)
- * neurology: neuralgia, neuritis, paresis, paralysis
- * vascular diseases: peripheral arteriopathy stage I - II, varicose veins stage I - II.
- * gynecology: adnexitis, non-specific metroadnexitis.
- * gastroenterology: biliary dyskinesia, ulcer disease, functional enteropathies.

6.8. Contraindications

- patients unable to cooperate or follow the therapist's instructions
- patients with a pacemaker

- patients undergoing anticoagulant therapy or with a history of pulmonary embolism or deep vein thrombosis, or whose skin is fragile and easily damaged/at risk of bruising (will not be treated with vacuum electrodes)
- pregnant women - applications on the trunk and pelvis
- suspected or certain malignant or benign diseases
- dermatological conditions: dermatitis, continuous skin lesions,
- patients at risk of hemorrhage and with marked circulatory problems
- infections, purulent inflammatory processes,
- febrile states,
- metal implants,
- tuberculosis

NOTE!!! Applications will not be made on: eyes, anterior part of the neck, carotid sinuses, active epiphyseal regions in children

Precautions

Care should be taken to keep the vacuum strength below the level of risk for injury or discomfort to the patient. If abnormal skin sensations are perceived, the electrodes should be positioned in another area to ensure effective stimulation. In the case of patients with fever, the result of the first treatment session should be monitored. Patients suffering from epilepsy, advanced cardiovascular diseases or cardiac arrhythmias should be treated after consultation with and in collaboration with a specialist physician. Treatments involving the placement of electrodes in the precordial area should be avoided. Transthoracic electrode applications are considered risky by many medical authorities.

6.9. Russian Current

The Russian protocol is a form of electrical stimulation designed to increase muscle strength. It was designed by Yadou Kots to develop the strength of Russian Olympic athletes¹. It has generated particular interest due to the success of the Russian Olympic team, which used this type of electrostimulation in addition to their regular training program. It has been suggested that the application of the protocol can generate increases in muscle strength of 30-40%.

In 1970 these observations were published, the study claiming that the application of an intermittent current of medium frequency of 2500 Hz (Russian current) can generate a muscle contraction with a force greater than that of a maximal voluntary muscle contraction.

This type of electrical stimulation is a polyphasic form of medium frequency alternating current with explosive modulations. It consists of 50 bursts/sec with 50 pulses/burst. The application lasts 10 seconds, followed by a 50 second break, repeated over a period of 10 minutes. The intensity is adjusted to cause a tetanic contraction, which is usually uncomfortable for the patient. There are multiple studies that indicate that this protocol has some benefits for muscle toning. There are also studies that support that adjustments can be made to the original protocol designed by Kots, which seem to be more appropriate and comfortable for the patient.

This protocol is also called the Tone Burst current.



¹ source: <http://electrotherapyforphysio.blogspot.ro/2012/11/russian-current.html>

² sursa: <http://dmeguide.hubpages.com/hub/Electrotherapy-Current-Waveforms-Commonly-Used-in-Medicine>

Although it is a form of medium frequency currents, the nerves are stimulated because the current is interrupted to allow for a low frequency stimulation of 50 Hz. Russian currents are alternating medium frequency currents of 2500 Hz, applied as a series of separate bursts with a pulse duration of 0.2 ms (200 μ s), interrupted for 10 ms (1000 μ s) of current of 50 bursts/sec (50Hz), which resembles the low frequency faradic current.

The theoretical basis for the use of this type of current is that electrical stimulation of almost all motor units in a muscle causes a contraction that cannot be obtained by voluntary contraction. This produces a very strong muscle contraction that will lead to hypertrophy.

6.9.1. Practice

Russian current is a form of neuromuscular electrical stimulation (NMES), the electrode placement for this type of electrical stimulation being identical to other forms of NMES.

The electrodes should be aligned along the muscle fibers of a muscle or muscle group. Two electrodes are used for applications to a single muscle. Four electrodes are used if simultaneous stimulation of cocontraction in the same muscle or muscle group is desired or for bilateral agonist/antagonist treatment.

Protocol for applying Russian currents:

Protocol for muscle toning/muscle hypertrophy:

Amplitude/Intensity: Tetanic contraction

Pulse rate: 50 – 70 Hz

Pulse duration: 150 – 200 μ s

Current is applied during voluntary activities exercises at various degrees of muscle amplitude

Slow isokinetic movements (movements in the same direction) 5 - 10° per second.

Short arcing joint movements, when the amplitude is limited.

Muscle spasm reduction protocol:

Amplitude: Tetanic contraction depending on patient tolerance

Pulse rate: 50 – 70 Hz

Pulse duration: 50 – 175 μ s

Isometric muscle contraction

6.9.2. Contraindications

<i>Applications on the cervical area:</i>	risk of stimulation of key organs such as the vagus, phrenic nerves, carotid sinuses, which may lead to adverse reactions such as hypotensive reactions or laryngeal spasm
<i>Applications on the thoracic region:</i>	risk of impairment of normal cardiac function; stimulation of the intercostal muscles may cause respiratory failure in a heart patient
<i>Applications on the cranial area:</i>	risk of impairment of normal cerebral function
<i>Pacemakers and arrhythmias:</i>	risk of interference with the respective device
<i>Patients with metallic implants:</i>	risk of severe pain due to overheating of the implant
<i>Hemorrhagic disorders:</i>	increased risk of hemorrhages as a result of increased blood flow thrombosis and thrombophlebitis (inflammation of the venous walls)
<i>Tendon transplant or repair</i>	
<i>Pregnancy:</i>	on the pelvis, lumbar area, abdomen
<i>Unconscious patient:</i>	misperception of information, with risk for treatment
<i>Recent radiotherapy</i>	
<i>Children with mental disorders</i>	
<i>Malignant diseases:</i>	risk of malignant cells spreading, due to increased blood flow in the area
<i>Infected wounds, skin lesions:</i>	risk of causing very severe pain (Belanger, A. Y., 2009)

7. HIGH FREQUENCY ELECTRIC CURRENT

7.1. Definition

The therapeutic application of high-frequency electric and magnetic fields and electromagnetic waves (69 cm decimeter waves and 12.25 cm microwaves) with frequencies above 300 kHz is high-frequency therapy.

These devices provide high-frequency pulses continuously. High-frequency generators operate on the same wavelengths as the radio network, thus being able to disrupt the reception of radio devices. The wavelength is a constant of each device.

High-frequency currents are alternating currents with an average frequency greater than 500,000 oscillations/sec.

Depending on the wavelength we have high frequency current with:

- long waves (d'Arsonvalization)
- medium waves (diathermy)
- short waves - used in therapy

7.2. Production mechanism

* the first devices are made up of the oscillating circuit, consisting of a coil and a capacitor and a "spark plug" ("spark plug"),

* the operating principle - the phenomenon of capacitor discharge when the potential difference between the capacitor's armatures overcomes the resistance of the air layer between them,

* by replacing the spark plugs with triodes, oscillations with a sustained character (equal amplitudes), continuous flow and increased frequency (between 10 and 100 MHz), with "short" wavelengths (great therapeutic importance).

7.3. Physical properties of high-frequency currents

- very high frequency,
- produce important capacitive and inductive phenomena,
- produce caloric energy (used in therapy); in a high-frequency electromagnetic field, electrical energy is transformed into caloric energy. The heat produced is directly proportional to the square of the intensity, resistance and duration of the current;
- the high-frequency field strongly heats metallic bodies and electrolytic solutions;
- high-frequency currents transmit electromagnetic waves of the same frequency as the current that generated them into the environment, at very great distances. The phenomenon is the basis of radiophony, radiolocation and television.

7.4. Physiological effects of high-frequency currents

- * have no electrolytic and electrochemical action (do not produce polarization phenomena),
- * do not cause neuromuscular excitation,
- * have deep caloric effects without causing skin lesions.
- * particular situations that influence the transfer and accumulation of caloric energy:
 - the distance of the electrodes from the skin (deeper effect increasing the intervention of the "capacitive" action)
 - the moisture of the skin (sweating) - its resistance decreases and the skin temperature increases through the intervention of the conduction phenomenon.
- * metabolic effects: the need for O₂ and tissue nutrient substrate increases, catabolism increases,
- * effects on circulation: active hyperemia, general vasodilation, decreased blood pressure,
- * effects on the nervous system:
 - CNS - sedative effect
 - Peripheral SN - increased excitability.

- * muscular effects: decreases muscle tone on hypertonic muscles,
- * increases the body's immunological capacity,
- * therapeutic effect deviated from the action of heat:
 - hyperemic,
 - analgesic,
 - muscle relaxant - antispasmodic,
 - activation of metabolism.

7.5. Application modalities

7.5.A.Capacitor field method

7.5.B. Inductor field method

7.5.A. Capacitor field method

- * types of electrodes used:

- Schliephake-type electrodes (round metal plates insulated in a glass or plastic capsule) also called "rigid" electrodes, with a diameter of 40, 85, 130 or 170 mm (fixed at a distance of up to 3 cm from the skin)

- flat or "flexible" electrodes (made of rubber, with different sizes and embedded in felt wrapped in an easily washable material) - are applied directly to the patient's skin and are used for the treatment of flat areas or immobilized patients.



Fig.29. Capacitor field method

- * the deep heating of the tissues and the adipose layer that is obtained is avoided by increasing the distance between the electrodes and the body surface,
- * greater heating on the surface is obtained by decreasing the distance between the electrodes and the body surface.

7.5.B. Inductor field method

- * types of electrodes used:
 - cable wound in a circular spiral (placed in an electrode sheath),
 - cable wound in a spiral (wrapped in felt),
 - cable wound in a spiral around the treated region = solenoid electrode (used on the limbs),
 - monode or minode type electrodes
- * the method of overheating the body in "pyrostat" type hyperthermic cabins can also be used.

7.6. General indications of high-frequency currents

- * rheumatology: degenerative rheumatism, chronic inflammatory rheumatism, abarticular rheumatism.
- * post-traumatic sequelae,
- * neurology:
 - peripheral SN - neuralgia, neuromyalgia, some neuritis, paresis and paralysis
 - CNS - some cases of multiple sclerosis, sequelae after poliomyelitis, myelitis and meningitis.
- * cardiovascular system: angina pectoris without myocardial damage or heart failure, disorders of peripheral venous circulation of the limbs.
- * respiratory system: chronic bronchitis, sequelae of non-tuberculous pleurisy, pleurisy, bronchial asthma between attacks

- * digestive system: esophageal, gastroduodenal, intestinal spasms of a functional nature, chronic constipation, biliary dyskinesia.
- * urogenital system: prostate hypertrophy, nephritic colic, epididymitis, some acute nephritis with anuria
- * gynecology: metroadnexitis, chronic parametritis, secondary sterility, some mastitis
- * ENT: sinusitis, chronic rhinitis, pharyngitis, laryngitis, otitis externa, oto-tubular catarrh.
- * ophthalmology: sty, iridocyclitis.

It is recommended to protect the lens by carefully dosing the therapeutic applications and avoiding foreign bodies accidentally entering the eye.

- * dentistry: post-tooth extraction pain, gingivitis.
- * dermatology: boils, felonies, abscesses of the sweat glands (hidrozadenitis),
- * endocrinology: disorders of the pituitary, thyroid, adrenal glands.

7.7. Contraindications

- * acute inflammatory processes with suppuration,
- * acute manifestations of rheumatic diseases,
- * diseases with bleeding tendencies,
- * neoplastic processes,
- * presence of intratissue metal parts,
- * cardiac pacemaker implant
- * menstrual cycle and pregnancy.

7.8. Practice

- * choice of electrodes depending on the desired effect,
- * size of electrodes should slightly exceed the affected area,
- * distance of electrodes from the treated area: 2 - 3 cm (increasing this distance leads to deeper heating),
- * position of electrodes: - can be applied bipolar or monopolar and must be placed parallel to the treated surface to achieve a uniform transmission field - heating
 - * oblique placement of electrodes determines the concentration of the field in the areas closer to them ("obliquity" effect)
 - * electrodes can be placed in three ways:
 1. transversely - in the treatment of joints,
 2. longitudinally - in applications in the back, trunk, limbs,
 3. at right angles
 - * intensity dosage - depending on the individual's sensitivity to heat; the nature of the treated region; the type, size and distance of the electrodes from the skin; the effect and therapeutic goal pursued; the stage of evolution of the condition being treated,
 - * intensity dosing can be subjective or objective,
 - * the objective method consists of measuring the temperature of the skin, subcutaneous tissues or mucous cavities,
 - * the subjective method consists of the character of the sensation of heat perceived by the individual at different doses of intensity applied,
 - * duration of sessions - depending on the therapeutic goal pursued:
 - in acute conditions: short durations (3 - 10 min.),
 - in chronic conditions: longer durations (20 - 30 min.)
 - * the number of sessions does not exceed 12 - 15 sessions.

8. SHORT WAVES

8.1. Definition

The high-frequency current with wavelengths between 10 and 100 m and frequency between 10 MHz - 100 MHz represents short waves. They are also called decametric waves. The short waves used in therapy have a wavelength of 11.06 m and a frequency of 27.12 MHz¹.

Physiotherapy with "short waves" is the most widespread procedure in the field of therapy (high-frequency currents) and also the oldest. In this therapy, heat is formed inside the body's tissues, unlike other therapeutic procedures, where heat is brought to the body from the external environment (hot baths, wraps, hot poultices, hot air and steam baths, etc.).

8.2. Physiological properties of short waves

- They do not have electrolytic and electrochemical action; consequently, they do not produce polarization phenomena;
- They do not cause neuromuscular excitation at high frequency, the stimulus duration being very short – below 0.01 ms – it cannot cause excitation of nervous structures;
- They have deep caloric effects without causing skin lesions; due to this main characteristic, high-frequency currents are used in deep-acting thermotherapy procedures.

Tissues behave as a complex conductor consisting of resistances and capacitances. The lower the frequency of the applied currents (towards direct current), the higher the tissue resistance to the current.

On the contrary, the higher the frequency of the current, the tissues behave as a capacitance, the current passing through the skin without heating it.

¹ This was established in 1947 at the Atlantic City Conference. Their therapeutic use began in 1930 – Schlliephake and 1959 – Ginsburg.

The skin itself behaves as a combination of capacitances and resistances arranged in parallel. The stratum corneum of the skin is an excellent insulator, the penetration of the current taking place through the vessels and sweat ducts. There are the following particular situations that influence the transfer and accumulation of caloric energy: - the distance of the electrodes from the skin has as a result a deeper effect, increasing the intervention of the capacitive action;

- when the skin is wet (in case of sweating), its resistance decreases and the skin temperature increases through the intervention of the conduction phenomenon: the phenomenon does not occur when the electrodes are spaced from the skin. The subcutaneous tissues react to high-frequency currents as a central electrolyte: the impedance of the skin to high-frequency currents is lower, so that the caloric energy accumulates more under the skin.

8.3. The effect of short waves on tissues

- increase the kinetic energy of particles in the body, producing heat;
- ionic particles oscillate rapidly (and generate the greatest amount of heat);
- dipoles undergo rapid rotational movements (especially water);
- nonpolar molecules undergo distortions of their electronic “cloud”.

Biological effects of short waves:

- Stimulation of blood circulation, especially on arterial and capillary microcirculation: classical thermotherapy acts more on larger blood vessels; short waves also produce dilation of veins
- Stimulation of lymphatic circulation
- Stimulation of local metabolic processes

Muscle relaxation (by reducing the tone of γ gamma cells)

- Pain reduction (directly on muscle fibers; through improving microcirculation)
- Effects on the blood: stimulation of phagocytosis; stimulation of leukocyte migration, decrease in clotting time.
- General effects - occur only in the case of irradiation of large anatomical regions: increase in temperature (by $1\div 30^{\circ}\text{C}$); decrease in BP, slight fatigue.

8.4. Methods of applying the treatment

Energia electromagnetică este transferată pacientului în două feluri:

Electromagnetic energy is transferred to the patient in two ways:

a) Capacitive method: the tissues to be treated are placed in the high-frequency field between the two electrodes.

Heating occurs in all tissues crossed by the electromagnetic field but with different values depending on the (dielectric) properties of each.

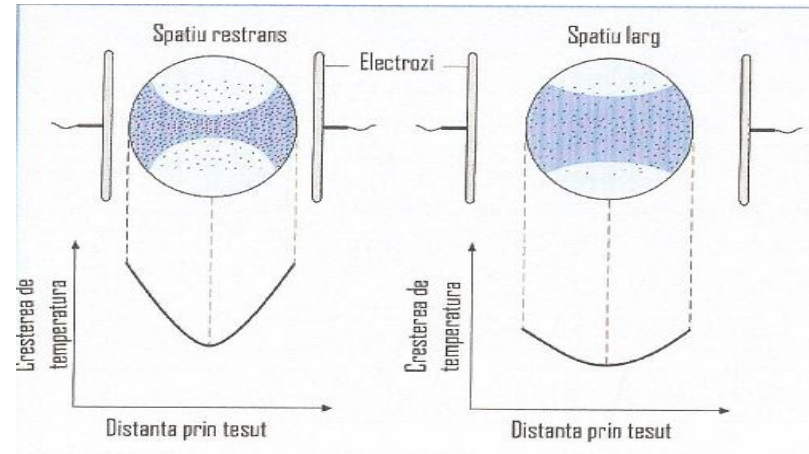


Fig.30. Relationship between electrode-tissue distance and degree of tissue heating

1. Metal electrodes are used in a plastic package
2. The radiation field is a strong electric and weak magnetic field.
3. The segment to be treated is placed inside the emitting coil (between the two electrodes).
4. The energy is absorbed more at the skin level and less in the deep tissues.
5. This type of application is generally suitable for areas with reduced adipose tissue.
6. The heating is superficial: the skin and adipose tissue are heated more than the muscle tissues.

The further the electrodes are from the skin, the greater the increase in temperature in depth and the more uniform the electromagnetic field is in the tissues.

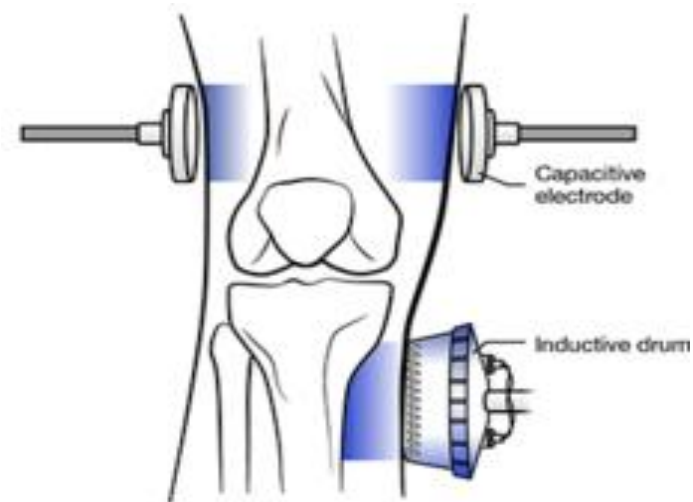


Fig.31 Capacitive/ Inductive method

It is usually placed 2÷4 cm from the skin, parallel to the skin surface. If one of the two electrodes is closer to the skin surface, more energy will be concentrated there and greater heating of the skin will be obtained. (Drăgan Adriana, 2007). The size of the electrodes is important. A smaller electrode concentrates the electromagnetic field so that a smaller electrode can be used to localize the treatment. (Fig.32)

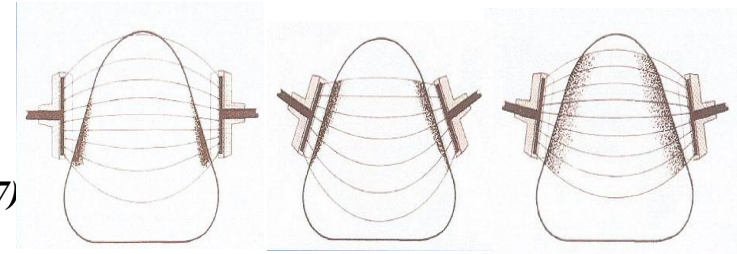
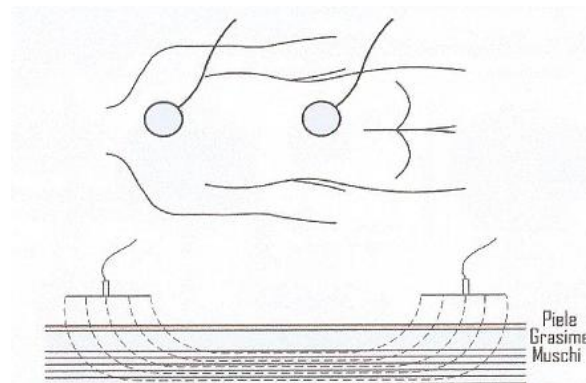


Fig.32. Creation of the electromagnetic field depending on the placement of the electrodes (Drăgan Adriana, 2007)

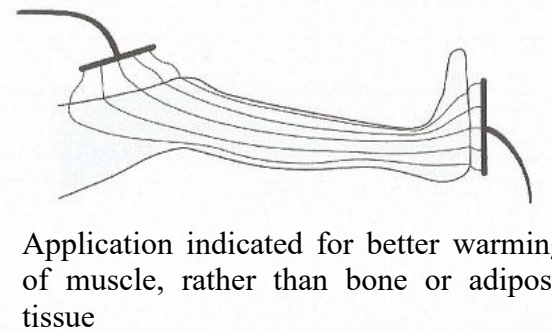
Electrode Positioning Methods

- transversală
- coplanară
- longitudinală

**Fig.33. Capacitive method.
Electrode placement
(Drăgan Adriana, 2007)**



The highest heat induced in superficial muscles
Application indicated for better warming of muscle tissue.



Application indicated for better warming of muscle, rather than bone or adipose tissue

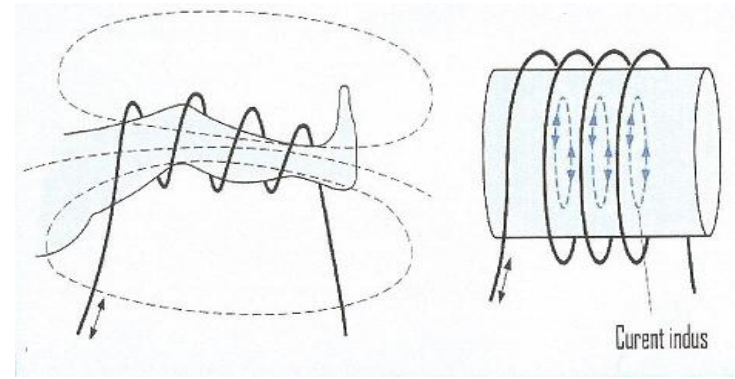
b) Inductive method: energia electromagnetică este aplicată prin intermediul unor bobine

1. Rigid, embedded metal coils
2. The radiation field is strong magnetic and weak electric
3. The energy is absorbed mainly in deep tissues; tissues with the highest electrical conductivity: muscle, synovial fluid.
4. The heating is deep.
5. Applications on areas with high water content.

There are two techniques:

- inserting the limb to be treated inside a coil. In this case the blood vessels and muscle fibers are parallel to the field lines);

Fig.34. The segment to be treated inside the transmitter coil



- using a coil as an applicator placed near the area to be treated. In this case the blood vessels and muscle fibers to be treated are perpendicular to the field lines. This method allows for a slightly more pronounced heating of the deeper muscles and a greater uniformity of tissue heating (see fig. 31).

The duration of the treatment depends on the type of pathology treated:

- acute conditions: 1÷5 minutes;
- subacute conditions: 10 minutes;
- chronic conditions: 15÷20 minutes.
- Treatment sessions are performed daily (acute, subacute conditions) or every 2 days (chronic conditions);
- The intensity is dosed depending on the type of device and the sensation of heat felt by the patient.

Dosage:

- athermic ($5 \div 10$ W);
- oligothermic ($10 \div 35$ W);
- thermal ($35 \div 100$ W);
- hyperthermic ($100 \div 250$ W).
- The treatment is applied to the skin (not through clothing); the patient must not have metal objects or synthetic materials on them within a radius of 30 cm around the area to be treated; the skin of the treated area must not be wet (sweaty) or covered with creams or ointments; regions with hormonal implants are not treated; the operator (assistant) must maintain a distance of at least 1 meter from the device during the treatment.

The anatomical protrusions of the human body concentrate the electromagnetic field and heat up more. (Drăgan Adriana, 2007)

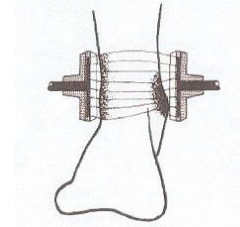


Fig. 35. Heating of bony prominences

8.5. Therapeutic indications

- Diseases of the musculoskeletal system: arthrosis (gonarthrosis, coxarthrosis, spondylosis, hand arthrosis, inflammatory rheumatism (periarthritis, myogelosis, myalgia), algoneurodystrophy and other post-traumatic sequelae);
- Diseases of the nervous system: myalgia, neuritis, lumbosciatica, paresis, paralysis, neuropathies, sequelae after poliomyelitis, multiple sclerosis);
- Vascular diseases: arteriopathy stage I – II, early disorders of venolymphatic return circulation
- Diseases of the renal system: prostatitis, renal colic, pyelocystitis;
- Gynecological diseases: adnexitis, metroadnexitis, parametritis, secondary sterility;
- ENT and dental diseases: sinusitis, pain syndrome, post-extraction dental, dental neuralgia, gingivitis, granulomas, periodontal diseases). (Dragan Adriana, 2007)

8.6. Contraindications

Absolute contraindications

- Presence of cardiac pacemaker or other types of stimulators. People wearing such devices should not stay less than 3m from an operating shortwave device.

Other contraindications

- Metallic tissue implants; endoprotheses;
- Non-removable metallic parts on the skin
- Pregnant uterus;
- Areas with bleeding risk
- Thermal sensitivity disorders;
- Ischemic tissue areas (e.g. arteriopathy stage III, IV or even II);
- Malignant tumors;
- Active tuberculosis;
- Febrile and infectious conditions;
- Severe organ failure;
- Venous thrombosis;
- Areas with acute fluid collections under tension (recent hematomas, acute bursitis, hemarthrosis);
- Patients who cannot remain still during the procedure (involuntary movements). (Drăgan Adriana, 2007)

8.7. DIAPULSE (short pulsed waves)

8.7.1. Definition

The pulsed high-frequency therapy generated by the DIAPULSE device provides high-frequency pulsed currents, with the following characteristics:

- * frequency of 27.12 MHz,
- * wavelength of 11.06 mm,
- * duration of the pulse train is 65 μ s, the duration of one pulse is in this case 0.036 μ s and one pulse train contains 1805 pulses

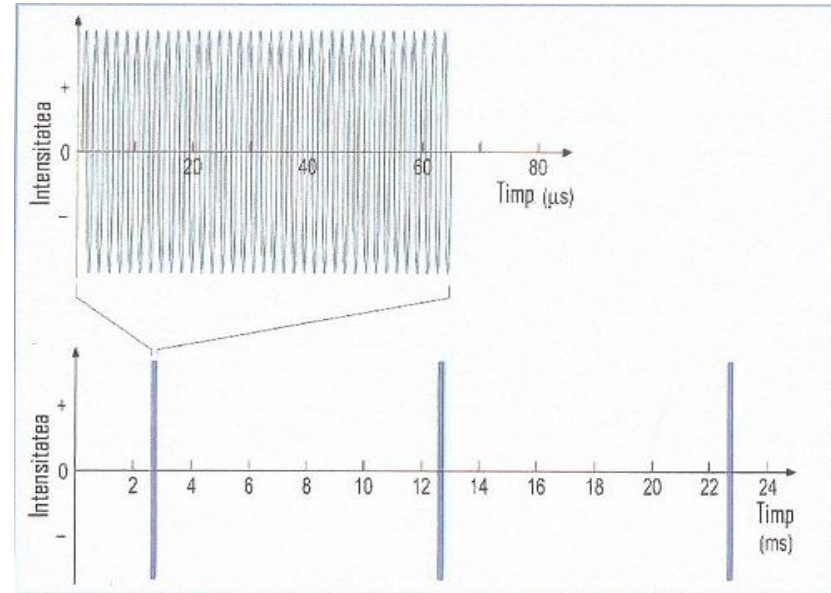


Fig.36. Short pulsed waves

- * the pulses are emitted intermittently, in "pulse trains", separated by pauses of 25 s, longer than the pulse duration,
- * the pulse frequency is dosed in 6 steps: 1- 6,
- * the intensity of the working energy of the device is between 293 and 975 W
- * the pulses generally have high intensity and very short duration, so that the heat produced during the pulse is quickly dissipated

8.7.2. Effect of pulsed shortwave therapy

Tissue heating

In accordance with the effects of pulsed shortwaves, tissue heating occurs during the shortwave action phase, but dissipates during the shortwave rest phase. Therefore, the treatment may not result in significant tissue heating (a treatment called non-thermal by therapists, since the skin is no warmer at the end of the treatment than it was at

the beginning). Clearly, there will be a small change in tissue temperature during the active shortwave phase. Figure (37A) demonstrates the lack of accumulation of thermal or nonthermal effects. Figure (37B) shows the pulses are close enough to generate a nonthermal cumulative effect, and Figure (37C) shows an accumulation of both thermal and nonthermal effects.

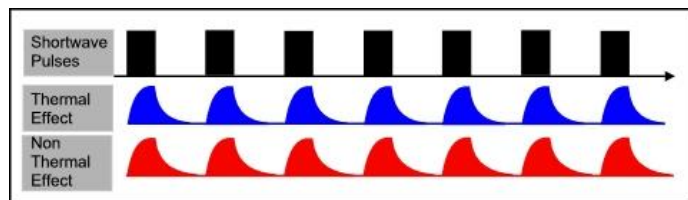


Fig.37A Pulses at sufficient distance – no cumulative effect

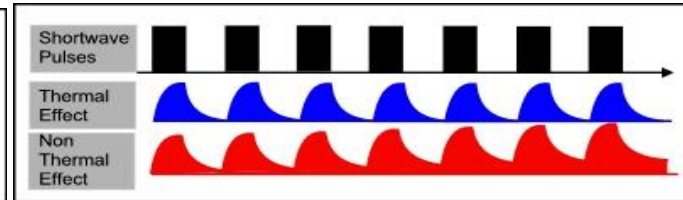
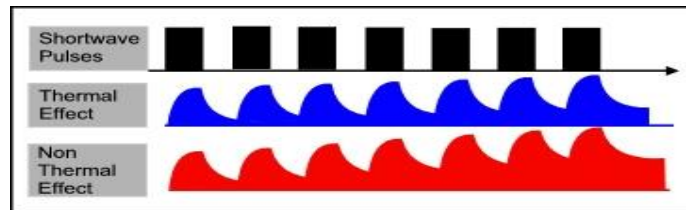


Fig. 37B Pulses 'close' – cumulative effect non-thermal, no thermal accumulation



*Fig. 37C 'Very close' pulses
– accumulation of thermal and non-thermal effects*

The settings will determine which of these effects will occur in a given treatment, with power being the most important parameter. Non-thermal effects are of great importance. They appear to accumulate over the course of the treatment and have a significant effect after a latency period of approximately 6-8 hours. It has been shown that the level of energy required to produce such an effect in humans is low (Hayne 1984, Al Mandeel and Watson, 2008).

If a non-thermal treatment is desired, it is essential that the average power applied remains below a level that produces significant tissue heating. Currently, this level is 5 Watts. If a thermal effect is desired, then a power greater than 5 Watts will be applied, but the therapist must take precautions, as with other thermal procedures.

The effects of pulsed shortwave therapy can be divided into two types – those of the electric field and those of the magnetic field. There is not much specialized literature or studies on the effects of the electric field, most of the studies being dedicated to the effects of the magnetic field. In the following, the bibliographical references concern the effects of the pulsed magnetic field (obtained through monod applications).

The first effect of the pulsed magnetic field occurs at the level of the cell membrane and refers to the transport of ions through the cell membranes. Some research demonstrates the nonthermal effect at the level of the cell membrane (Luben 1997, Cleary 1997).

The membranes of normal cells have a potential difference due to the different concentrations of ions on either side of the cell membrane. The most important of these are sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), chlorine (Cl^-) and bicarbonate (HCO_3^-). The membrane potential varies depending on the type of cell, but a typical membrane potential is 70mV, internally negative. It is actively maintained and therefore cellular energy (ATP) must be used to maintain this potential. A cell involved in an inflammatory process has a reduced membrane potential, and the cell's function is thus disrupted. The altered potential affects the transport of ions across the membrane, thus causing an ionic imbalance that alters the cellular osmotic pressure.

The application of short-wave pulsed therapy to the affected cells will have the effect of restoring normal membrane potential values, restoring transmembrane ionic transport and regulating ionic balance. The mechanism by which this effect occurs is not yet known, but there are two theories that suggest either a direct action on the ionic transport mechanism or the activation of pumps (sodium/potassium) (Sanseverino 1980). Some studies (Luben & Cleary 1996) support the idea that energy is absorbed in membranes and through a signal transduction mechanism, stimulates or enhances intracellular effects. It seems that there is a great similarity between the mechanisms of effects of ultrasound, laser and short-wave pulsed therapy – all three modalities seem to have the first effect on the cell membrane, where the regulation of cell behavior seems to be the key to these therapeutic effects.

It has been shown that energy applied to normal cells has no or negligible effect on them, while diseased cells respond to lower energy levels than healthy cells.

The clinical effects of pulsed shortwave therapy are primarily related to the inflammatory and reparative phases of musculoskeletal and soft tissue. The effects are similar to those of ultrasound and laser therapy – which is not surprising, given their common mode of action. The difference in clinical use is given by the site where the energy is absorbed, rather than the effect obtained.

The difference in tissue absorption is shown in the following figure:

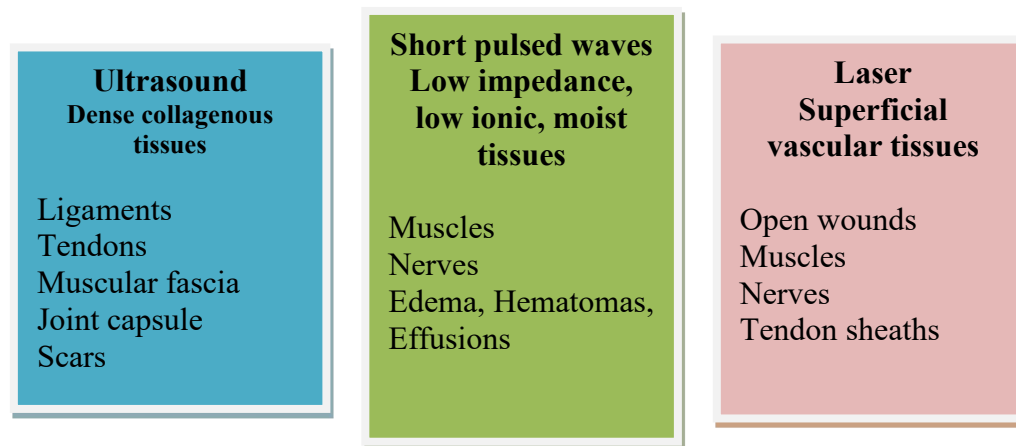


Fig.38. The difference between the place of tissue absorption of ultrasound, short pulsed waves, laser

Goldin et al. (1981) list the following primary effects of short-wave pulsed therapy:

- 1) Increase in the number of white blood cells, histocytes, and fibroblasts at the wound site
- 2) Improve the rate of edema dispersion
- 3) Improve hematoma absorption
- 4) Reduce inflammatory processes
- 5) Increase in the rate of orientation of fibrin fibers and collagen deposits

- 6) Promoting collagen stratification in early stages
- 7) Stimulating osteogenesis
- 8) Promoting the healing of the central and peripheral nervous system.

Important biological effects:

It has been found that in pulsed form, short waves have different effects than those obtained in continuous form

- * no tissue heating occurs
- * stimulation of cellular metabolism - anabolic phase
 - stimulation of the reticulo-histiocytic system, synthesis of gamma globulins, leukocytosis and leukocyte migration, stimulation of phagocytosis; stimulation of hematopoiesis and collagen synthesis.
- * anti-pain effect
- * anti-hemorrhagic effect
- * stimulation of lymphatic circulation;
- * antispasmodic effect on smooth muscles, muscle relaxation (by reducing the tone of γ gamma cells)
- * biostimulation, acceleration of tissue healing
- * resorption of edema and hematomas
- * pronounced stimulation of peripheral circulation
- * faster healing of fractures

8.7.3. Proposed treatment doses

It is difficult to determine which parameters are more important in dose selection. There are still many fundamental questions to be answered regarding treatment selection, such as whether the total energy produced or the mode of delivery is more important. Current research indicates that the minimum energy necessary to produce therapeutic effects should be used. The following general guidelines are based on current clinical and scientific evidence:

Acute conditions: - average power less than 3 Watts (the more acute the condition, the lower the power will be - 3 Watts is the maximum for this group of conditions); using narrow pulses (with short duration) and a high number of repetitions, the effect is beneficial

- 10 min. of treatment is adequate

Subacute conditions: - average power between 2 and 5 Watts (the less acute the condition becomes, the wider the waves will be used - the longer the duration)

- treatment time: 10 - 15 minutes

Chronic conditions: - average power greater than 5 Watts is necessary to obtain a reasonable tissue response. The thermal component will be considered, especially since at powers over 12 Watts or higher, the patient can perceive the heating effect. Longer pulses are more beneficial.

- Time: 15 - 20 minutes.

8.7.4. Indications

- * musculoskeletal system: fractures, algoneurodystrophy
- * chronic degenerative rheumatism
- * non-articular rheumatism: bursitis, tendonitis, tenosynovitis, capsulitis, enthesitis
- * inflammatory rheumatism: rheumatoid arthritis, ankylosing spondylitis, calcific myositis
- * cardiovascular system: peripheral arteriopathy, varicose ulcers
- * respiratory system: acute bronchitis, acute pharyngitis
- * digestive system: acute gastroduodenitis, gastroduodenal ulcers, colitis, ulcerative colitis.
- * urogenital system: acute cystitis, acute pyelonephritis, non-specific pelvic inflammations (adnexitis, metroadnexitis, parametritis, adhesion syndrome
- * dentistry: gingivitis, stomatitis, alveolar poireia.
- * ENT: acute sinusitis, acute chronic sinusitis.
- * dermatology: bedsores, decubitus ulcers, continuity lesions, hypertrophic scars, burns, cellulitis.

8.7.5. Contraindications

- Pacemaker wearers: some, but not all pacemakers can be affected by continuous or pulsed shortwaves. Current recommendations state that there should be a distance of at least 3 m between a patient with a pacemaker and an operational shortwave system.
- Pregnancy: due to potential adverse effects on the fetus, pregnant women have a major contraindication to shortwave treatment
- Bleeding
- Malignant pathologies (shortwaves and lasers have the ability to increase the rate of division of malignant cells, and in these conditions, they should be avoided).
- Active tuberculosis:
- avoid treatment on the abdomen or pelvis during menstruation (a precaution rather than a contraindication)
- severe circulatory disorders, such as: ischemia, thrombosis and associated conditions
- deep X-ray or other ionizing radiation therapy (in the last 6 months) on the affected area
- patients unable to understand the therapist's instructions or cooperate

Precautions: - avoid the eyes and active epiphyseal regions in children

8.7.6. Principles of application of short-wave therapy

The duration of treatment is shorter than in continuous applications: 10÷15 minutes (depending on the type of device used). Sessions are performed daily or every 2 days, a total of 10-12 sessions (depending on the clinical evolution of the case).

Acute diseases are treated with lower frequencies of impulse trains < 82 Hz and chronic ones at higher frequencies. Studies indicate the occurrence of the therapeutic effect at a dose of at least 40 kJ/24 h, with an optimum at 100 kJ/24 h.

The applicator is a coil wrapped in plastic, applied to the skin.

Pulsed short waves are not applied to pacemakers or other stimulators, to pregnant uteruses or to areas with neoplasia or precancerous conditions.

Short waves can be applied to wet skin or to skin with metal implants.

The choice of frequency and penetration level is determined by:

- localization of the pathological process,
- intensity or duration of the pathological process: acute, subacute, chronic,
- somatic constitutional type: - ergo tropic/tropho tropic.
- thickness of subcutaneous adipose tissue crossed by high-frequency electromagnetic energy

Frequency in acute conditions is 400, penetration 4,

Frequency in chronic conditions is 600, penetration 6,

Rhythm: one session per day,

Variable duration: 10' - 15' - 20',

Number of sessions: - 4 - 8 in acute conditions,
 - 10 - 14 in chronic conditions.

Experience in the field recommends that regardless of the location and characteristics of the pathological process, the 10' region should be irradiated with 1 - 2 steps lower than the therapeutic frequency step:

- right hypochondrium: stimulates hepatic vascularization,
- epigastrium: reflexogenic stimulation of the solar plexus,
- lumbar: stimulation of the adrenal glands.

Therapist Safety

It is recommended that after switching on the shortwave treatment device, the therapist and any other personnel keep a distance of at least 1 m from the operating machine, wires and electrodes. Almost all devices turn off automatically. It is recommended that any other electrotherapy device be kept at a distance of at least 2 m from the shortwave device. Two shortwave devices should not be operated simultaneously unless there is a distance of at least 3 m between them.

8.8. Microwaves

8.8.1. Definitions

Microwaves are electromagnetic radiation with frequencies between 300 MHz ($\lambda = 1$ m) and 300 GHz (with $\lambda = 1$ mm). They are used in telecommunications (mobile telephony) and in radars (radar waves), for guiding airplanes, satellites, ships.

Microwaves used for medical purposes have the following frequencies (according to the Atlanta Conference):

- 2450 MHz with wavelength $\lambda = 12.2$ cm;
- 915 MHz with wavelength $\lambda = 32.8$ cm;
- 434 MHz with wavelength $\lambda = 69.1$ cm; (in air)

Most medical devices used in physiotherapy have 2450 MHz. Microwaves are produced by an electronic device called a magnetron, which generates a high-power alternating current, which reaches an antenna that emits microwaves. The microwave beam produced by this antenna (transmitter) is divergent and not uniform.

8.8.2. Physiological effects

The physiological effects of microwaves in tissues are similar to those of short waves.

The physiological effect is the heating of tissues which is proportional to the amount of radiation absorbed.

Microwaves are intensely absorbed by tissues with a rich ionic content (blood vessels, muscles).

Upon contact with the skin and subcutaneous fat, 50÷75% of the microwave beam is reflected.

The reflection phenomenon also occurs at the boundary of separation between different tissues (bone-muscle, fat-muscle).

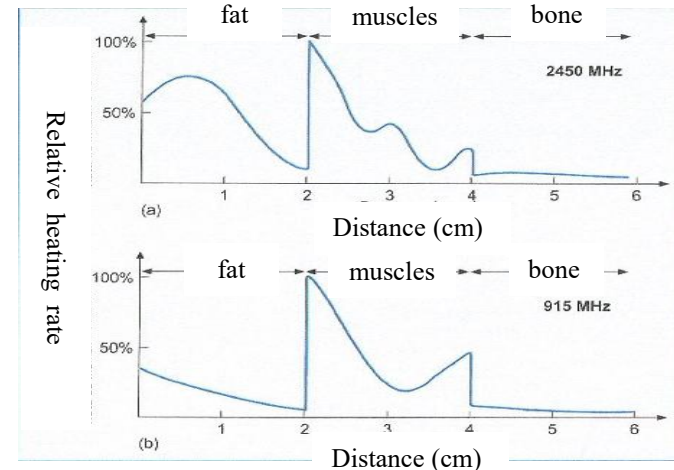


Fig.39. Heating rate

The half-life of the microwave beam is 3.5 cm in fat and bone tissue and 0.7 cm in muscle tissue (at 2450 MHz). The shape of the anatomical surfaces to be treated influences the depth of penetration.

Microwaves are used to heat tissues, especially muscle tissue, which is located deeper.

Heating the tissue leads to:

- pain reduction;
- increase in local tissue metabolism;
- stimulation of local repair processes.

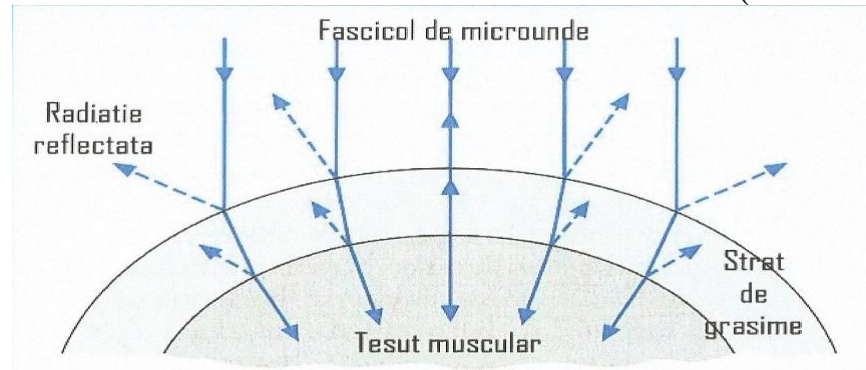


Fig.40. Radiation reflection (microwaves)

8.8.3. Application technique

- The patient is positioned and the treated area is exposed;
- The therapy is explained to the patient and the condition of the skin is inspected;
- The emitter is chosen according to the size of the area to be treated;
- The emitter is not applied through clothing;
- The patient should not wear metal objects on him (especially in the treated area); there should be no metal surfaces near the emitter that could reflect microwaves;
- The patient will sit on a wooden chair or bed;
- The patient feels a pleasant local warmth; he will signal if the sensation of heat becomes very intense;
- The sweat accumulated on the skin is removed (it reflects most of the radiation);
- At the end of the procedure, the treated area is inspected;
- The duration of the treatment is 15÷20 min or 30 min (for very strong heating);
- The intensity of the therapy is chosen according to the sensation of heat felt by the patient (200 mW/cm² produces a slight sensation of heat);

- The patient must have intact thermal sensitivity and must be able to communicate.

Microwave emitters can be applied:

- a) directly to the skin (to avoid losses caused by reflection);
 - have lower emission power (max. 25W);
 - have smaller size (have a diameter of 1.5 cm or 3.5 cm);
 - can also be applied in natural cavities (rectum, vagina, external auditory canal).
- b) Remote emitters:
 - have higher power (25W ÷ 150W);
 - have a large emission surface (oval, circular shape).

8.8.4. Contraindications

- Cardiac pacemaker (or other stimulating implants);
- Eye exposure causes cataracts; wear glasses (protected by metal);

NOTE. Not to be confused with those from laser or ultraviolet!!!! Closing the eyes reduces but does not prevent the transmission of microwaves to the eyes.

- Pregnant uterus;
- Tissue areas subject to irradiation;
- Acute inflammations, collections (hemarthrosis, bursitis, arthritis);
- Tissue areas with impaired circulation.

For therapists, professional exposure is negligible if during operation of the transmitter a distance greater than 1 m in front of it or 25 cm behind it is maintained, for a power of 100 W. For a power of 200 W the distances are 1.4 m in front and 35 cm behind the transmitter.

9. ULTRASOUND

9.1. Definition

Sound is a mechanical vibration of particles in an elastic medium, which can be perceived by the human ear ($\nu = 20 \text{ Hz} \div 20 \text{ kHz}$). The human ear perceives sounds whose upper limit of perception is about 20,000 oscillations/second.

Mechanical pendulum vibrations - representing sound - that exceed this limit are called ultrasound (they have a frequency estimated at 50,000 Hz - 3,000,000 Hz).

Ultrasound is therefore a mechanical vibration (like sound), with a frequency greater than 20 kHz.

Ultrasound provided by devices used in physiotherapy have a frequency between 800 - 1,000 Hz.

Ultrasound treatment is a medical treatment with mechanical vibrations with a frequency greater than 20 kHz. In practice, the following are used: - $\nu = 0.7 \div 3 \text{ Mhz}$ for therapy and - $\nu = 5 \div 13 \text{ Mhz}$ for diagnosis (ultrasound)

The application of ultrasonic waves to a body produces an energy transfer by alternating pressure states. Sound waves propagate in a straight line at a constant speed, with an average value in human tissue of 1500 m/sec.

Ultrasonophoresis is the medical treatment in which a medicinal substance is introduced into the body using ultrasound energy.

Ultrasound is a longitudinal wave (its direction of propagation coincides with the direction in which it oscillates). The practical importance of ultrasound is related to its short wavelength. For this reason, ultrasound can be emitted and propagated like light rays in the form of beams, unlike ordinary sounds that spread in all directions.

The human body is an elastic medium, and therefore can be penetrated by ultrasound.

$$c = \lambda \cdot f$$

c = viteza de propagare US (m/s)

λ = lungimea de undă (m)

f = frecvență (Hz)

In water and soft tissues, the average propagation speed of ultrasound is 1500 m/s. The speed is higher the denser the medium.

- in air: $c = 340$ m/s
- in bone: $c = 2800$ m/s
- in skin: $c = 1519$ m/s
- in cartilage: $c = 1665$ m/s
- in tendons: $c = 1750$ m/s
- in fatty tissue: $c = 1478$ m/s

The wavelength λ of ultrasound is:

- 1.5 mm in water at 1 Mz
- 3 mm in bone tissue at 1 Mhz.

The physical characteristics of the media traveled by ultrasound are represented by the acoustic impedance [Z] of the respective medium. Z is therefore a material constant.

$$Z = \rho \cdot c \quad \text{where} \quad \begin{array}{l} \rho = \text{density [kg/m}^3\text{]} \\ c = \text{propagation speed [m/s]} \end{array}$$

9.2. Ultrasound properties

- * presents vibrations depending on the nature of the medium it passes through (gaseous, liquid or solid),
- * ultrasound intensity defined by the transfer of ultrasonic energy, applied and measured in W/cm²; it is an important parameter in ultrasound therapy,
- * ultrasound propagation - only in a straight line in the form of a beam of rays and depends on the type and shape of the production source, the coupling with the medium in which it propagates and the frequency (high frequency - high penetration),
- * the notion of "half-life" means the halving of the energy in the unit of space (the depth at which the ultrasonic energy is halved from 1 W administered to the surface),

When passing through the human body, ultrasound undergoes the following phenomena:

a) REFLECTION: consists in the return to the original medium of a part of the ultrasound beam, when crossing an interface, depending on the acoustic impedance $[Z]$ of the two media. The direction of the reflected beam depends on the angle that the incident beam makes with the interface. The more different Z is, the greater the reflection. The greatest reflection occurs at the muscle-bone interface (30%). The acoustic impedance of the body is identical to that of the gel used in ultrasound.

Reflection is at the interface:

- skin – air: 100%
- fat tissue - muscle: 0.8%
- transducer (aluminum) - air: 100%.

b) REFRACTION: represents the change in the direction of the incident beam after it has crossed an interface. The value of the refraction angle is directly proportional to the difference in the speed of ultrasound in the two media and inversely proportional to the angle of incidence.

Reflection and refraction of the sound wave occur at the boundary between two different tissues. Reflection and refraction at frequencies of 1 and 3 Mhz do not differ very much, because the acoustic impedance of the media crossed is the same and the speeds of ultrasound travel do not differ very much.

c) SCATTERING: in tissues, mainly due to reflection, the ultrasound beam scatters, the ultrasound energy thus acting not only in the direction of the beam, but also in the vicinity. Ultrasound does not leave the body, because at the skin-air interface the reflection is 100%.

d) INTERFERENCE: due to reflection, the incident and reflected ultrasound interfere, leading to the formation of more intense standing waves. In practice, this phenomenon is important when treating areas of the body such as the wrist or ankle, where a thin layer of muscle is located above the bone and the standing waves of interference formed can cause irritation of the periosteum and cause pain.

e) ABSORPTION: the biological effects of ultrasound are manifested only if they are absorbed by tissues.

Absorption is measured by the absorption coefficient. Absorption at 1 Mhz is:

- bone: 3,22,	- fat tissue: 0,14,	- muscle: 0,76,
- skin: 0,62,	- water: 0,0006.	

The depth of half-life is the distance measured in the direction of ultrasound propagation, at which the intensity of the ultrasound beam is reduced by half.

It is known that in general, the depth of half-life is 3 cm in muscle, but this is only true when the ultrasound is parallel to the muscle fibers. If the ultrasound is perpendicular to the muscle fibers, the depth of half-life is 9 mm. In general, ultrasound therapy can reach a depth of 3 ÷ 4 cm, to have noticeable effects.

The forms of ultrasound used in therapy are:

- * continuous field ultrasound - a longitudinal, uninterrupted sound waveform, with continuous action on the environment, producing the so-called "internal tissue micro massage",
- * discontinuous field ultrasound - the rhythmic interruption, with a certain frequency, of continuous field ultrasound.

<i>Depth of halving</i>	<i>1MHz</i>	<i>3MHZ</i>
<i>Bone</i>	2,1 cm	---
<i>Skin</i>	11,1 cm	4 cm
<i>Cartilage</i>	6 cm	2 cm
<i>Muscle</i>	9 cm	3 cm
<i>Fat tissue</i>	50 cm	16,5 cm
<i>Water</i>	11.500cm	3833,3 cm

9.3. Production mechanisms

- * mechanical processes = setting in vibration a fixed metal blade of certain dimensions or a tuning fork,
- * magnetic processes = the magnetostrictive generator, which is based on the principle of changing the dimensions of some metals by periodic magnetization using an alternating current,
- * piezoelectric process = is based on the property of some crystals (quartz, lead, etc.) cut in a certain section, to compress and expand in a certain direction if they are subjected to variations in electric potential.

9.4. Biological effects of ultrasound

a) MECHANICAL EFFECT

In tissues, (elastic medium) ultrasonic waves produce repeated compressions and decompressions, with the frequency of ultrasound, producing pressure variations with a micromassage effect. The highest intratissue pressures occur at the boundary of separation between two media with different acoustic impedances (e.g. muscle-bone).

As a result: - cell volume can change by 0.2%,
- membrane permeability can change,
- metabolic exchanges can improve.

b) THERMIC EFFECT

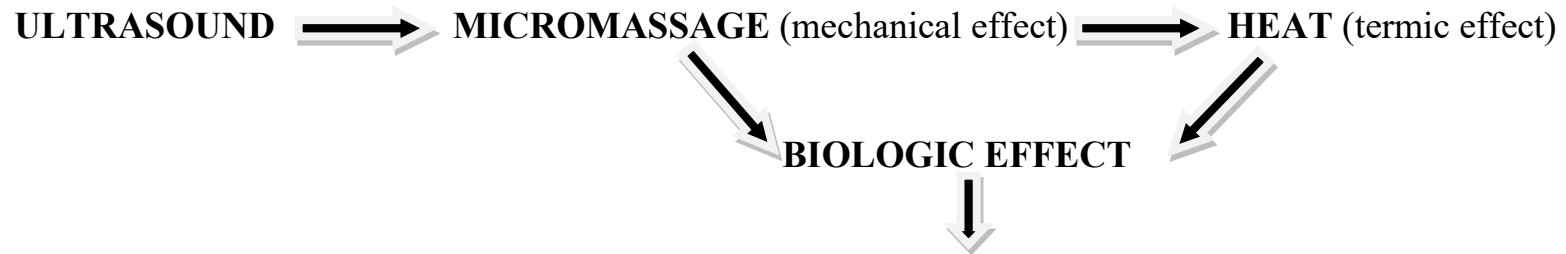
Micromassage leads to the release of heat. Tissue heating is marked at the boundary of separation between tissues, where reflection and interference phenomena occur. Ultrasound applied continuously at 1.5 W/cm², for 5 minutes, with a 12.5 cm² transducer, can increase the temperature: - in the muscle by 3.30C
- in the bone by 9.30C
- in the joint capsule by 6.30C.

Heating (which occurs strictly under the ultrasound head) can be avoided:

- by using pulsating ultrasound;
- by continuously moving the ultrasound head.

Tissue heating produced by ultrasound is to be avoided in some pathological situations such as arthritis, sprains, dislocations, contusions (immediately after trauma).

9.5. Physiological effects of ultrasound



- * analgesics - achieved through the CNS, by direct stimulation of unmyelinated nerve fibers
 - improvement of microcirculation (including lymphatic);
 - muscle relaxation and reduction of tissue pH;
 - * muscle relaxant effect: - by activating microcirculation and eliminating catabolic products;
 - by direct action on nerve fibers.
 - * hyperemissive action,
 - * increased membrane permeability (by continuous and pulsed applications): as a result, tissue pH is reduced and some medicinal substances can be introduced into the tissues.
 - * activation of blood circulation (microcirculation) by:
 - increase in temperature;
 - stimulation of vascular smooth muscle;
 - release of some substances from cells, as a direct consequence of mechanical vibrations.
 - * action on the SNV,
 - * effects on peripheral nerves: ultrasound can modify nerve conduction by both increasing and decreasing it.
- The effects on the central nervous system have not been fully elucidated. A sympatholytic effect has been described, used in reflex applications.
- * inhibition of the action of the pituitary gland,
 - * fibrolytic effects (related to tissue fragmentation and rupture phenomena),

- * anti-inflammatory effects,
- * vasomotor and metabolic action.
- * increased tissue regeneration power: it has been experimentally proven that the effects of stimulating tissue regeneration are obtained with 0.5 W/cm² in pulsed application with a frequency of 3.5 Mhz.

NON-THERMAL EFFECTS

1. Cavitation effect: It occurs only when high ultrasound intensities are used and consists of the formation of gas bubbles in the tissue. These bubbles are $1 \div 100 \mu\text{m}$ in size. The phenomenon of cavitation has been experimentally obtained in the nervous tissue of the cat brain, at intensities of $100 \div 180 \text{ W/cm}^2$. In water applications of ultrasound, cavitation leads to the appearance of gas bubbles that must be removed.

2. Standing waves: are produced as a result of the interference phenomenon at the boundary of separation between two media with different acoustic impedances and lead to very high ultrasound intensities, which can destroy tissues. In practice, this does not occur because:

- living tissues have an extremely inhomogeneous structure;
- the continuous movement of the ultrasound head avoids the formation of standing waves.

9.6. Practice

Application modalities:

Direct coupling: the ultrasound head is applied directly to the skin through a gel with the following characteristics:

- acoustic impedance similar to tissue;
- very good ultrasound transmission;
- chemically inactive;
- hypoallergenic and sterile (relatively).

In addition to gels, oil or various ointments can also be used.

Fig.41. Ultrasound therapy



Indirect coupling: - is achieved by immersing the ultrasound head and the area to be treated in water;

- is used when small anatomical areas, such as the hand or foot, need to be treated, or when ultrasound cannot be applied directly due to pain;

- the water temperature must be pleasant ($36\div 37^{\circ}\text{C}$)

- the water must be boiled beforehand, to eliminate dissolved gases;

- the "water cushion" method can also be used, a plastic or rubber container filled $\frac{3}{4}$ with water, placed above the area to be treated; a large part of the ultrasound energy is lost in this way.

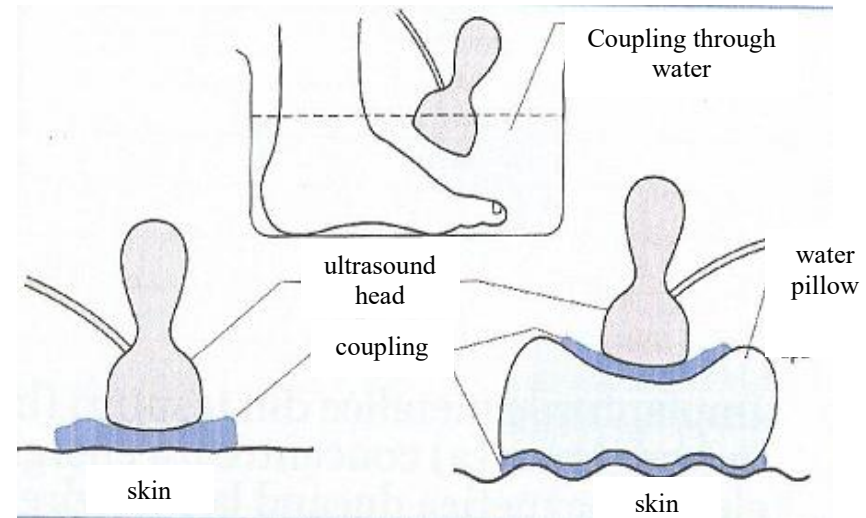


Fig.42. Types of coupling

Treatment parameters:

- **continuous or pulsed mode;**

- ultrasound intensity [W/cm^2]: Therapeutic doses range from $0.3\div 3 \text{ W}/\text{cm}^2$.

- a) low intensity: $< 0.3 \text{ W}/\text{cm}^2$;

- b) medium intensity: $0.3\div 1.2 \text{ W}/\text{cm}^2$;

- c) high intensity: $1.2 \div 3 \text{ W}/\text{cm}^2$.

For pulsed US, the average intensity of the pulsations is calculated. The muscle relaxant effect is greater with pulsed ultrasound. Acute conditions (post-traumatic conditions, arthritis) are treated with pulsed ultrasound because we do not need to heat the tissues. Chronic conditions are treated with continuous ultrasound.

The intensity used in the treatment is chosen according to: the size of the area to be treated; the depth where the lesion is located (max. $0.5 \text{ W}/\text{cm}^2$ near the bones); the type of lesion.

- **frequency:** 1 MHz frequency (deep pathological processes and 3 MHz for superficial pathological processes).
- **direct/indirect coupling;**
- **type of ultrasound head:** The ultrasound field emitted by the ultrasound head is not uniform. Therefore, the intensity of the emitted ultrasound is an average intensity; the movement of the sample on the patient uniformizes the intensity. Its length depends on the size of the surface of the ultrasound head and the wavelength.

The ultrasound intensity specified on the device is the average intensity measured in water at 5 mm from the ultrasound head.

The length of Fresnel zone in cm for different sizes of the transducer and different sizes				
Transducer diameter	Frequency (MHZ)			
	0.75	1	1,5	3
2	5 cm	6,7 cm	10 cm	20 cm
3	11 cm	15 cm	23 cm	45 cm
5	31 cm	41 cm	63 cm	125 cm

Treatment area. A surface of max. $75 \div 100 \text{ cm}^2$ can reasonably be treated in one treatment session. Maximum treatment time: 15 min. A tissue surface of $3 \div 6 \text{ cm}^2$ can be treated in $3 \div 5 \text{ min}$.

The ultrasound heads have surfaces ranging from $1 \div 5 \text{ cm}^2$. The ultrasound head moves continuously over the treatment area. Ultrasound head movement:

- (a) circular;
- (b) in the form of a figure 8;
- (c) transverse.

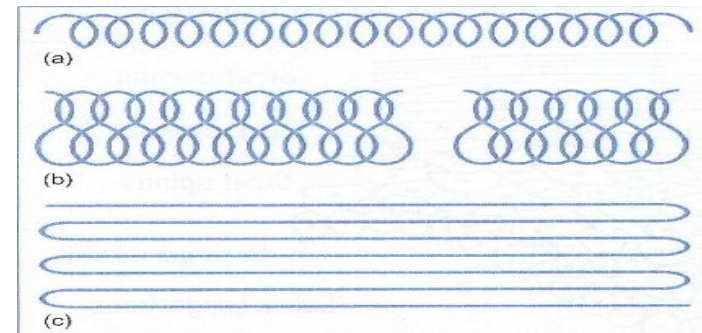
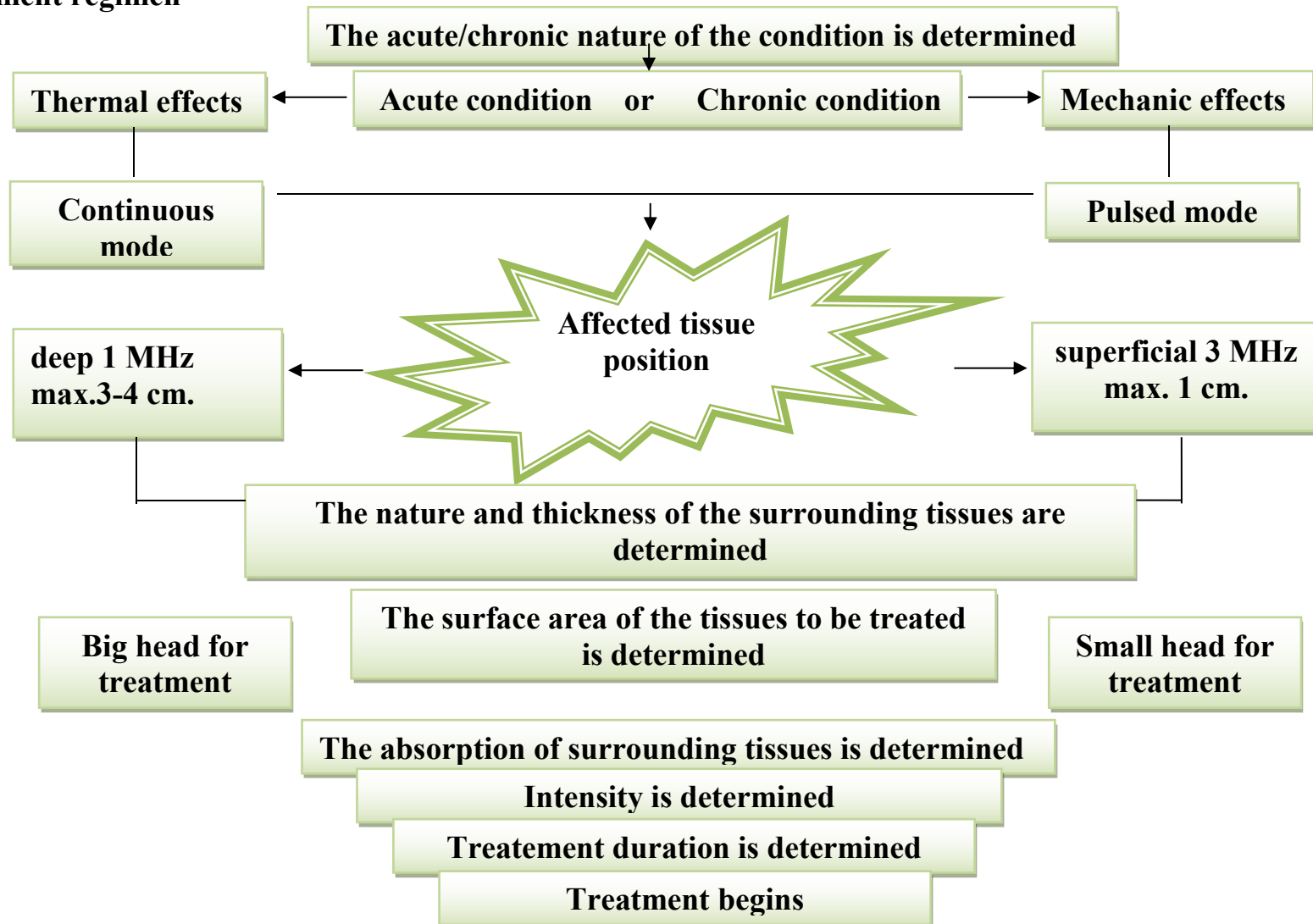


Fig.43. Ultrasound head movement

Treatment regimen



Dosage time:

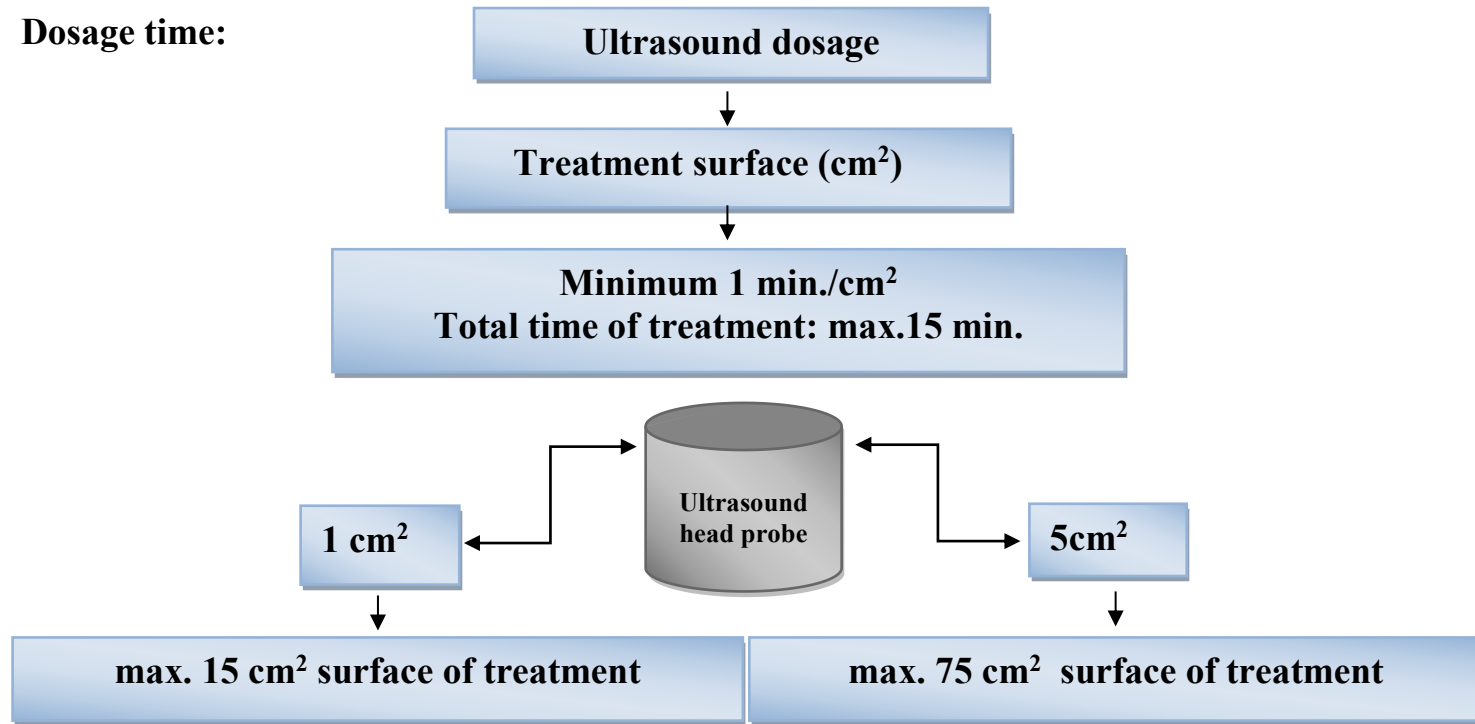


Fig.44. Algorithm for choosing treatment time

Treatment technique

- * the patient is informed about the treatment and its goals; it is checked whether there are any contraindications;
- * ensuring thermal comfort in the room,
- * the body in a state of general thermal equilibrium (in case of peripheral segments with poor circulation, partial warm baths are recommended to activate local circulation)

- * the bed or chair on which the patient will be placed must be made of wood,
- * the patient is positioned for treatment, relaxed, without pain;
- * the skin region to be treated is inspected; if necessary, it is cleaned with 70% alcohol (fats, makeup, etc.);
- * the treatment parameters are set;
- * precise dosage of intensity,
- * the device's power switch and the clock indicating the session duration are activated,
- * the treatment is started by continuously moving the ultrasound head;
- * communicates with the patient constantly;
- * the sensations that can be felt are: slight warmth, pain reduction, dizziness, headaches, fatigue, tingling;
- * at the end of the therapy, the treated skin area is inspected
- * for conditions located in the upper limb, the treatment is applied indirectly to the paravertebral regions between C4 - T1, in the areas corresponding to the affected segment (shoulder, arm, forearm),
 - * it is not applied to the paravertebral region above C3,
 - * segmental application for conditions in the lower limb (hip, thigh, calf, foot) - on the lower and external edge of the sacrum, on the sacroiliac joint area and the lumbar and lower thoracic paravertebral,
 - * direct segmental application is done neurally, along the peripheral nerves in a caudal to cranial direction,
 - * reflex applications - on dermatomal skin areas corresponding to internal organs,
 - * ultrasound application should not be immediately followed by another procedure,
 - * the therapeutic sequence massage - ultrasound or vice versa in the same half-day is not indicated (maneuvers with similar action),
 - * it is the simultaneous application of X-ray therapy and ultrasound therapy to the same area is contraindicated,
 - * ultrasound applications may precede the physiotherapy session

9.7. General indications

- * rheumatic diseases: degenerative rheumatism, chronic inflammatory rheumatism, abarticular rheumatism
- * traumatology: recent fractures, delayed callus formation, contusions, sprains, dislocations, hematomas, bad postures, scoliosis, foot deformities
- * dermatology: keloid scars, atonic wounds, trophic ulcers of the limbs
- * collagen tissue disorders: fibrositis, dermatomyositis, scleroderma, Dupuytren palmar aponeurosis retraction.
- * neurology: neuralgia and neuritis, neuralgic sequelae after herpes Zoster, neuromas of amputations, progressive muscular dystrophy, spastic and hypertonic syndromes
- * circulatory diseases: obliterating arteriopathy, Raynaud's disease
- * diseases within internal medicine
- * gynecological diseases.

9.8. Contraindications

9.8.A. General contraindications:

- * skin changes, various skin diseases, skin sensitivity disorders,
- * blood coagulation disorders, capillary fragility,
- * altered general conditions, cachexia, feverish conditions,
- * tumors in all evolutionary stages (pre/postoperative),
- * active tuberculosis,
- * acute inflammatory phenomena, acute articular rheumatism,
- * cardio-respiratory insufficiency, coronary insufficiency, cardiac rhythm disorders,
- * venous disorders of the limbs: thrombophlebitis, thrombosis, varicose veins.
- * progressive calcification of the arterial walls: atherosclerosis

9.8.B. Special contraindications:

- * application of ultrasound to areas corresponding to organs and tissues such as: brain, spinal cord, liver, spleen, pregnant uterus, sex glands, lungs, heart and great vessels,
- * applications to areas of bone growth in children and adolescents.

The following tissues and organs are not treated with ultrasound:

- eyes;
- heart;
- pregnant uterus;
- brain (above the C3 vertebra);
- testicles;
- epiphyseal growth cartilages (in children); they can however be treated with pulsed ultrasound;
- tumors (at any stage);
- thrombophlebitis and varicose veins;
- septic and febrile conditions;
- cachexia, altered general condition;
- infectious skin diseases, allergic inflammations;
- active TB;
- organ failure (liver, kidney, heart, respiratory).
ratorie).

9.9. Ultrasonophoresis

Represents the introduction of medicinal substances into the body using ultrasound.

Substances used:

- corticosteroids;
- vasodilators (methyl nicotinate);
- histamine;
- anesthetics (xylene).

Ultrasound increases membrane permeability, does not electrically charge the respective substances (no unpleasant sensations occur) and allows their deeper penetration (6 cm).

9.10. Combined therapy

Represents the simultaneous application of ultrasound with a low or medium frequency electrical stimulus; the method was introduced by Gierlich. Advantages: combined stimuli have a more pronounced effect than if they act separately; time is gained when applying the therapy, it complements the effect of the current.

Ultrasound is combined with:

- diadynamic current;
- Trabert current;
- low frequency current (with pulses);
- medium frequency alternating current.

Ultrasound complements the effect of the current, preventing the occurrence of the adaptation phenomenon; the electrical stimulus is more effective; it can be applied for a longer period and with a lower intensity.

Combined therapy with medium-frequency current:

- acts more deeply;
- is more pleasantly tolerated than that with low-frequency current.

The active electrode is the ultrasound head and represents the (-) pole (cathode). The contact medium must conduct the electric current.



Fig.45. Combined therapy

10. FOTOTHERAPY

10.1. Definiție

Phototherapy or "light therapy" represents the use of the action on the body of radiant light energy. It can be:

- natural (sunlight),
- artificial (provided by the radiation spectra emitted under certain conditions by heated bodies).

The use of light for therapeutic purposes = sunbathing.

10.2. Fundamental properties of light

* rectilinear propagation in a homogeneous medium, the reflection of light is its return to the medium from which it comes, the reflected ray being in the same plane as the incident ray; the angle of reflection equal to the angle of incidence,

* refraction is the deviation that a light ray undergoes when passing through the surface separating two media with different densities,

* lack of mutual perturbation (when the beams intersect, they propagate independently),

* interference is the phenomenon of "composition" of light waves with the same direction of propagation (light and dark bands),

* diffraction is the phenomenon of bending the light path in the region of the geometric shadow,

* polarization is the dependence of the intensity of reflected light rays on the orientation of the plane of incidence.

10.3. Production mechanism

- * the emission of energy by bodies is done by:
 - incandescence: (in the case of heating bodies); depending on the absorbed caloric energy, a heated body emits radiation with different wavelengths,
 - luminescence: (or cold emission) is not done by the consumption of caloric energy by the emitting body but based on chemical, electrical, mechanical or biological processes.
- * energy is needed to tear away the expelled electrons from molecules or atoms, which, by rearrangement, emit quanta of light energy: photons,
- * the two theories on the nature of light are:
 - wave theory: based on electromagnetic radiation (a transverse sinusoidal vibration propagated in vacuum at a constant speed of 3.10 cm/s)
 - electromagnetic radiation is characterized by:
 - wavelength,
 - frequency (number of vibrations/sec.),
 - time period,
 - number of waves per centimeter,
 - corpuscular, photonic or quantum theory: based on the phenomena of emission and absorption of light, as well as photoelectric phenomena.
 - corpuscular, photonic or quantum theory: based on the phenomena of emission and absorption of light, as well as photoelectric phenomena.
- * the actual light radiations, which are the subject of phototherapy are:
 - infrared radiation,
 - visible radiation,
 - ultraviolet radiation.

10.4. Physiological effects of light

* on metabolic processes:

- oxidation processes in the body increase,
- blood sugar decreases proportionally to the intensity of irradiation,
- glycogen deposition in the liver and muscle tissue increases,
- activation of muscle metabolism,
- stimulation of protein catabolism,
- increases the elimination of nitrogen, phosphorus, sulfur,
- formation of vitamin D,
- increases the calcium and phosphorus levels, increases the intestinal absorption of dietary calcium.

* on blood elements:

- the number of erythrocytes and the globular value decrease,
- the number of leukocytes in venous and capillary blood increases,
- the number of platelets increases,
- decreases in cholesterol values.

* on circulation:

- activation of the skin and deep circulation,
- increases the superficial blood flow,
- increases the deep circulation,
- the pulse accelerates,
- increases the cardiac output in the right heart by 10%.

on breathing:

- increases the amount of oxygen absorbed,
- rarer and more extensive respiratory movements.

- * on the digestive system:
 - increases gastric acid secretion,
 - increases gastric and intestinal motility,
 - stimulation of salivary and pancreatic secretion.
- * on the endocrine glands:
 - stimulation of the parathyroid glands,
 - stimulation of the glucoregulatory function of the pancreas,
 - decreases the secretory activity of the thyroid,
 - changes in the function of the adrenal medulla, pituitary, gonads and thymus.
- * on the nervous system:
 - initially an exciting action followed by a prolonged sedation phase until sleep,
 - nerve chronaxy decreases,
 - muscle contractility increases at normal temperatures and decreases at temperatures above 44° C,
 - reflex decrease in sympathetic tone,
 - excitation of the parasympathetic component, causing vasodilation, hypotension, increased glucose tolerance,
 - reversal of the oculo-cardiac reflex (pulse acceleration instead of bradycardia),
 - decrease in excitability and pain sensitivity with more pronounced analgesia at high doses.

10.5. Infrared radiation (IRR)

10.5.1. Definition

Infrared radiation is electromagnetic radiation, also called heat radiation, with wavelengths between 760 millimicrons and 1 mm. In the electromagnetic spectrum, it is located between microwaves and visible light.

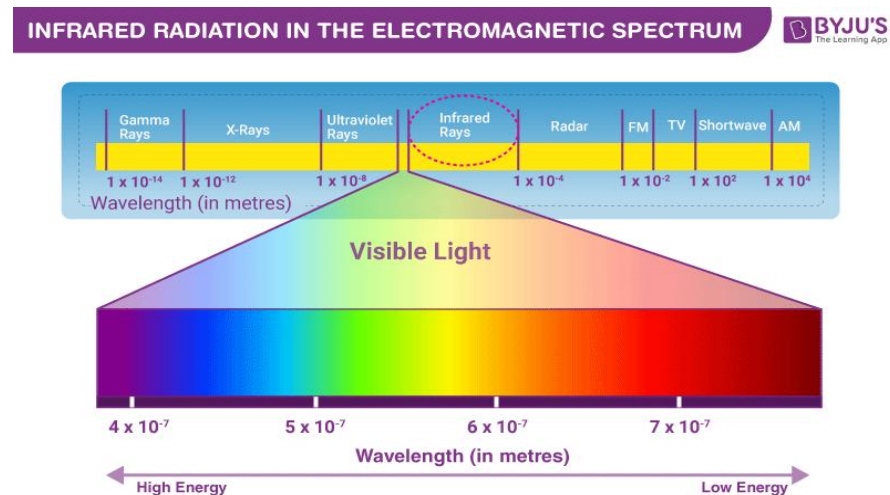


Fig.46 The electromagnetic spectrum of infrared rays¹

Infrared radiation is divided by wavelength into three regions (or bands): A, B, C, which have distinct absorption characteristics.

IRA : 760 nm ÷ 1400 nm

IRB : 1400 nm ÷ 3000 nm

IRC : 3000 nm ÷ 1 mm

Infrared radiation types A and B are used therapeutically.

¹ source: <https://byjus.com/physics/electromagnetic-spectrum-infrared-rays/>

Classification of infrared radiation:

- “near” or “short” infrared: 760 nm ÷ 1500 nm
- “far” or “long” infrared: 1,500 nm ÷ 15,000 nm

Infrared is produced by any material body in which there is molecular vibration, including the human body (IR type C). Any raised object emits IR and the higher its temperature, the higher the frequency of the IR emitted (and the lower λ). Infrared radiation is produced by passing an electric current through an emitting resistance. (Drăgan Adriana, 2007)

10.5.2. Mechanism of production

- * are emitted by incandescent bodies of gases brought to luminescence by electric discharges
- * in therapeutics the following classification is used:

1. RIR with wavelengths between 760 mμ and 1500 mμ - are penetrating depending on pigmentation, degree of inhibition, temperature and dose,
2. RIR with wavelengths between 1500 mμ and 5000 mμ, absorbed by the epidermis and dermis,
3. RIR with wavelengths greater than 5000 mμ, absorbed only at the surface of the skin.

Medical devices that produce IR are called lamps and contain an emitter placed in a reflector (parabolic) that forms a radiation beam that is applied to the patient; the lamp has a movable support from which the distance from which the therapy is applied can be adjusted.

According to the emission power, IR lamps can be:

- Small lamps: 250 ÷ 500 W
- Large lamps: 750 ÷ 1000 W

Their emission wavelength is between 3000 ÷ 4000 nm. At the skin surface, infrared radiation, like any electromagnetic wave, undergoes the following processes:

- reflection
- scattering
- absorption.
- refraction

63% of IR radiation is absorbed by the skin, leading to tissue swelling. The depth of penetration into the tissues is between 0.1 mm and 3 m.

10.5.3. Physiological effects

- * caloric action (the shorter the wavelength, the deeper the caloric action), arteriolar and capillary vasodilation (caloric erythema)
 - directly on blood vessels
 - indirectly through the release of vasodilator mediators
- * slight edema of the mucous layer,
- * edema of the dermal papillae,
- * perivascular leukocyte infiltration,
- * increased blood flow,
- * increased local metabolism and improved trophicity,
- * activation of sweat glands,
- * influences nerve endings with consequent relief of neuralgia
- * sweating
 - In chronic, long-term application, IR can produce: - skin pigmentation
 - skin aging

Therapeutic effects of IR

- Pain reduction
- Muscle relaxation
- Acceleration of repair processes
- Reduction of joint stiffness

IR can be used to prepare tissues before kinetic procedures (stretching, traction, massage, etc.)

10.5.4. Application method

A. Light baths: - general and partial.

B. Applications in open space

A. General light baths:

- * procedures that use the action on the body of infrared radiation emitted by incandescent lamps, applied in a closed space,
- * devices used: - in the form of a hexagonal cabinet equipped with a door (mobile wall) through which the patient enters, and an opening for the head at the top,
- * the patient, completely undressed, sits on a chair with adjustable height,
- * the door and the halves of the lid at the top are closed, so that heat cannot escape,
- * a cold compress or cold hot water bottle is applied to the patient's forehead or neck and changed every 5 minutes,
- * the bulbs are turned on by manipulating the switches,
- * the temperature inside the bath and the patient's condition are monitored,
- * after the session is finished, a cooling procedure is applied (washing with water at 22° C).
- * for the partial light bath, the same procedures are applied but depending on the area treated (cervical, shoulders, limbs).

B. Applications in open space:

- * does not cause sweating (it does not act by heating the air around the body but by direct action of the rays sent by the lamp, giving a sensation of progressive heat followed by uneven redness or even pigmentation),
- * devices used: SOLLUX lamp, VITALUX lamp, SOLLEX lamp, etc.
- * parameters that must be respected:
 - distance from the source to the irradiated skin (the intensity of the radiation varies inversely proportional to the square of the distance) - applications are usually made at 50 - 80 cm.

- radiation intensity:
 - moderate (pleasant sensations),
 - medium (clear but bearable sensation),
 - strong or very strong,
 - intolerable.
- session duration: - between 5 - 20 min., depending on the desired effect,
- the region indicated for irradiation is left uncovered for the procedure.

* it is recommended to monitor the patient to prevent possible burns

* an appropriate temperature in the room must be ensured.

* the lamp is placed $60 \div 70$ cm from the surface to be treated (large 1000 W lamps) or $45 \div 50$ cm (small $250 \div 500$ W lamps). The IR beam must be perpendicular to the area to be treated. The patient must feel a sensation of intense, pleasant heat (no burns!).

* metal objects (watch, jewelry) are removed from the area to be treated.

* at the end of the procedure, the appearance of the skin is checked, which should be slightly hypertonic.

* treatment sessions are performed daily.

* the duration of a session is $5 \div 20$ min (depending on the type of lamp used)

10.5.5. Indications for RIR therapy

A. In open space:

- * local diseases accompanied by inflammatory edema and superficial stasis,
- * various types of neuralgia, myalgia, tendinitis,
- * cutaneous, subacute, chronic catarrh of the mucous membranes,
- * postoperative wounds, atonic wounds, frostbite, eczema, actinic erythema, radiodermatitis, vicious scars,
- * peripheral circulation disorders,
- * spastic conditions of the abdominal viscera.

B. In closed space:

- * diseases with low metabolism: obesity, hypothyroidism,
- * degenerative rheumatic diseases, abarticular rheumatism (myalgia, trauma, myogelosis, bursitis, periarthrititis)
- * various neuromyalgias,
- * chronic heavy metal poisoning,
- * chronic and subacute inflammatory diseases of the genital organs,
- * chronic diseases of the respiratory system.
- * abdominal colic syndromes.

10.5.6. Contraindications

- * do not apply immediately after trauma,
- * areas with bleeding risk, recent bleeding, risk of gastrointestinal bleeding,
- * acute inflammations, suppurations, diseases and feverish conditions
- * skin lesions: dermatitis, eczema
- * skin tumors or precancerous lesions
- * skin areas with circulatory disorders or thermal sensitivity

10.6. Ultraviolet radiation (UVR)

10.6.1. Definition

Ultraviolet radiation¹ is radiation in the electromagnetic spectrum between visible light and X-rays, with a wavelength between 100÷400 nm. In therapy, only those between 400 and 180 mμ are used. Ultraviolet is classified into three groups:

1. Ultraviolet A (I) - or long waves of 400 - 315 mμ (abundant spectrum of sunlight) - biotic
2. Ultraviolet B (II) - or medium waves of 315 - 280 mμ (emitted by mercury lamps)
3. Ultraviolet C (III) - or short waves below 280 mμ (electrical discharges in mercury vapor) - abiotic

Sunlight contains all types of UV radiation, but at ground level it is mainly type A that reaches, because type C (more aggressive) and partially type B, are stopped by the oxygen-ozone layer of the atmosphere.

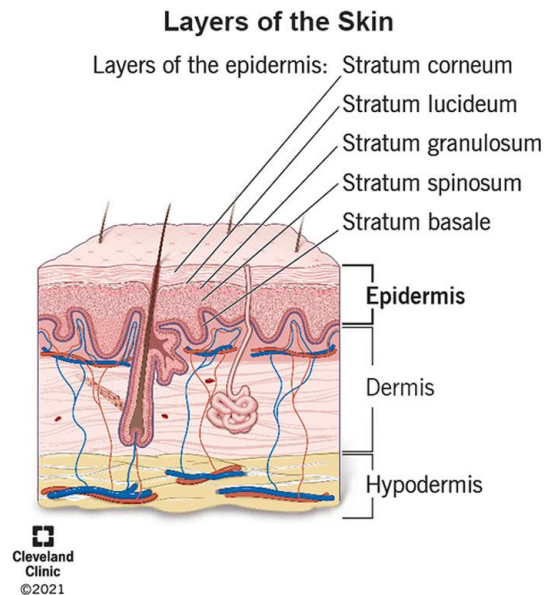
Sunlight: 95 ÷ 98 % UVA
5 ÷ 2 % UVB + UVC (at ground)

Ultraviolet radiation acts mainly on the skin.

It has three layers: epidermis, dermis, hypodermis.

a) **the epidermis** is made up of layers of epidermal (epithelial) cells, 80% of which are keratinocytes (which store a protein called keratin) and other types of cells: melanocytes and Langerhans cells with an immune role.

Fig.47. Structure of the epidermis²



¹ They were named by Johann Ritter in 1801. They were widely used to treat tuberculosis until the discovery of tuberculostatic drugs. Currently, their use is more restricted, with dermatological indications being the mainstay.

² source: <https://my.clevelandclinic.org/health/body/21901-epidermis>

A keratinocyte takes 28 days to reach the stratum basale in the stratum corneum. The stratum corneum is made up of dead keratinocytes and prevents water loss, protects the body from viruses and bacteria. It also protects the body from UV. It is covered by sebum, produced by the sebaceous glands. Skin pigmentation is given by melanin, a pigment produced by melanocytes, in specialized organelles called melanosomes. These melanosomes travel through the dendritic processes of melanocytes to reach keratinocytes.

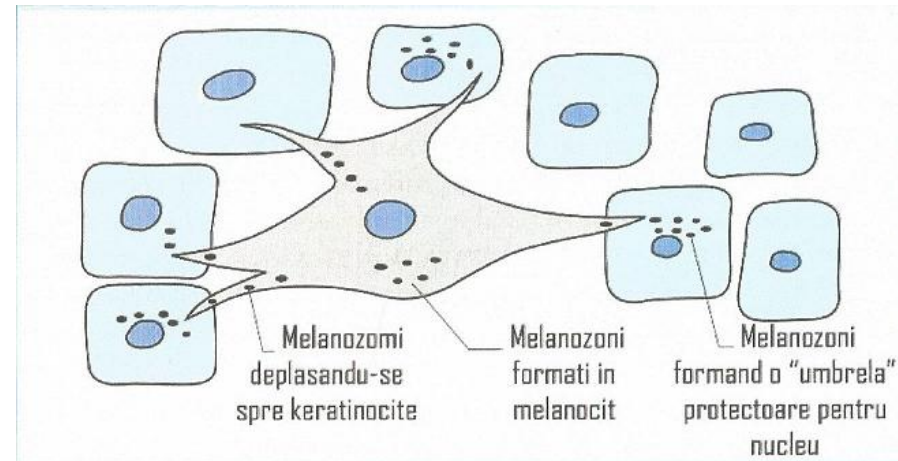


Fig.48. Melanosomes movement towards keratinocytes

Melanin protects keratinocytes from UV by absorbing them before they reach the nucleus, where ultraviolet rays can damage DNA. The most sensitive keratinocytes are those in the germinal layer, which undergo intense division processes. UV with a wavelength of $\lambda = 290 \div 400$ nm (UVB) stimulates melanin production.

The other layers of the skin:

b) dermis: contains blood vessels, vascular plexuses, tactile corpuscles, fibers, nerves, connective tissue.

c) hypodermis: contains adipose tissue

10.6.2. Production of ultraviolet radiation

MERCURY VAPOR LAMPS

This lamp is made in the form of a balloon covered on the inside with a layer of phosphor 2. Rarefied inert gas is introduced inside the balloon. The electrical discharge (in the form of an electric arc) between electrodes 3 and 4 occurs in a quartz tube in which an atmosphere of argon and mercury vapor is created, which during operating temperature reaches several atmospheres.

FLUORESCENT LAMPS

They consist of a tube containing mercury vapor, coated with a phosphor layer on the inside and with electrodes on the ends subjected to a voltage. These lamps emit mainly UVA along with visible light.

ALPINE LAMPS

Or “high altitude” lamps. These also contain mercury vapor in the emitting tubes but the UV spectrum emitted resembles that of sunlight at high altitude; small amounts of ozone are also produced in the air around them, and therefore the place where they are located must be well ventilated. $\lambda < 270 \text{ nm}$.

KROMAYER LAMP

It is intended for use in direct contact with the skin or mucous membranes of natural cavities of the body. Ultraviolet rays have the same physical properties as electromagnetic radiation (reflection, refraction, absorption, etc.).

Ultraviolet (UV) is measured by:

- Irradiance = power of radiation emitted per unit surface area (W/cm^2); measured with a photometer
- Radiant exposure - represents irradiance multiplied by exposure time $\text{ER} [\text{J}/\text{cm}^2] = \text{I} [\text{W}/\text{cm}^2] \cdot \text{time} [\text{s}]$

10.6.3. Physiological effects

Effects of ultraviolet rays

They can be classified into:

- a) Acute (rapid, immediate) - actinic erythema (aktis = ray)
 - pigmentation (melanogenesis)
- b) Long-term (slow) - effects on pigmentation
 - hyperplasia of the dermis, epidermis and stratum corneum, with skin aging
 - immunosuppression (at the skin level)
 - production of vitamin D

Physiological effects

- * vasodilator (erythema),
- * skin pigmentation,
- * skin exfoliation,
- * vitamin D production,
- * antiallergic desensitizing effect,
- * antialgic effect,
- * electropoiesis stimulating effect,
- * bactericidal, virucidal effect,
- * psychological effect,
- * resorption of superficial edema,
- * stimulation of catabolism and sweating

Pathological effects

- Induction of changes leading to skin cancers (malignant melanoma)
- Photodermatoses (solar urticaria, pigmentosum, prurigoactinic)
- Photosensitization after consumption of some drugs: tetracyclines, retinoids, methotrexate, chloroquine, hydroxychloroquine, griseofulvin, ibuprofen, naproxen, celecoxib
 - UVB and UVC produce conjunctivitis and photokeratitis ("snow blindness") with inflammation of the corneal tissue; the most dangerous for the eyes are UVB with $\lambda=270$ nm
 - long-term exposure to UVA can cause cataracts, opacification of the lens

10.6.4. Heliotherapy

It represents the treatment applied to the whole body by exposing it to sunlight (which contains UVA, UVB and infrared radiation, along with visible light). It has been used since ancient times (Greece, Rome). In the 19th century it was used to treat tuberculosis.

Heliotherapy is done progressively by increasing the exposure time from 10 min. to 3 hours. The best time of day for heliotherapy is 900 -1100 in the morning.

Therapy with the help of sunlight has beneficial effects on the body, rebalancing it metabolically, hormonally, even from a psychological point of view.

Recently, a real phobia has been established towards sun exposure, as a result of campaigns promoting the negative effects that it involves (risk of skin cancer, sunburn, etc.). Beyond protective measures that everyone should take against excessive exposure to sunlight, sun phobia is a danger.

Depriving the body of natural light is fundamentally wrong, because it prevents the body from synthesizing vitamin D. This has the antioxidant properties of a vitamin, but also plays the role of a true hormone, because it intervenes in the metabolism of calcium and phosphorus. Vitamin D stimulates the intestinal absorption of calcium and its renal reabsorption.

10.6.5. Application modalities

A. General irradiations:

- * on groups of people or individually,
- * the room must be ventilated, heated,
- * the subject in a static position (lying down, sitting) or in motion,
- * when applying in a stationary position half of the time is irradiated (the front half of the body), then the other half of the time is irradiated the back of the body,
- * the lamp placed perpendicularly, at the same distance throughout the session; it will be put into operation 5 min. before application,
- * the distance between the lamp and the body - 150 cm,

- * the duration - progressive, from one min. to 15 min., increasing by 1 min. at each session (for each side),
- * number of sessions - 10 - 20 sessions with an average of 15 sessions,
- * radiation dose - depending on the purpose,
- * session rhythm - depending on their intensity,
- * repetition of the exposure series is resumed after a minimum of 6 weeks.

B. Local irradiation:

- * is performed in well-defined "skin" fields (rectangular or square), the rest of the skin surface is covered with a sheet,
- * the rhythm of the sessions - every 1 - 2 days, depending on the condition.

10.6.6. General indications

* **dermatology:** alopecia, pelade, psoriasis, acne, keloid scars - irradiation of 1 - 2 weeks, eczema (subacute, chronic stages), furuncles and anthracoid furuncle, frostbite, erythema pernio, herpes zoster (Zona), lupus vulgaris, skin ulcers, nipple cracks, pyoderma, prurigo, skin mycoses.

* **pediatrics:** rickets, spasmophilia, bronchial asthma, physical debility, craniotabes.

* **rheumatology:** rheumatoid arthritis, arthrosis, periarthritides, neuralgia, AND syndrome.

* **phthisiology:** tuberculosis

* **other diseases:** - neurovegetative syndromes, endocrine disorders, ENT diseases, obstetric diseases.

10.6.7. Contraindications

- | | |
|---|---------------------------------------|
| * active pulmonary tuberculosis, neoplasms, | * liver and kidney failure, |
| * pigmentation disorders, solar skin photosensitivity | * hemorrhagic conditions, |
| * cachexia of any cause, starvation, | * hyperthyroidism, diabetes mellitus, |
| * decompensated heart disease, heart failure, | * nervous and irritable patients, |
| * hypertension, | * pregnancy. |

11. LASER THERAPY

[Low intensity laser therapy – LILT:
Low level laser therapy – LLLT]

11.1. Definition

LASER stands for **LIGHT AMPLIFICATION by STIMULATED EMISSION of RADIATION**.

In common terms, a laser can be considered a kind of light amplifier, which emphasizes/exploits certain properties of light energy. The laser behaves according to the basic laws of light, according to which it propagates in space in a straight line, with a constant speed. It can be transmitted, reflected, refracted and absorbed.

It can be included in an electromagnetic spectrum according to the wavelength/frequency, which can vary depending on the generator.

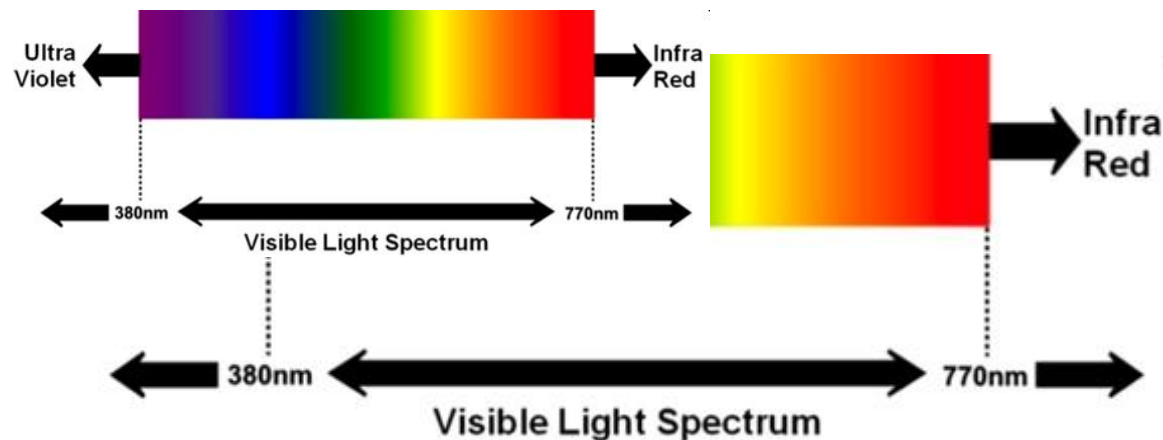


Fig.49. Visible light spectrum (source: <http://www.electrotherapy.org/modality/laser-therapy>)

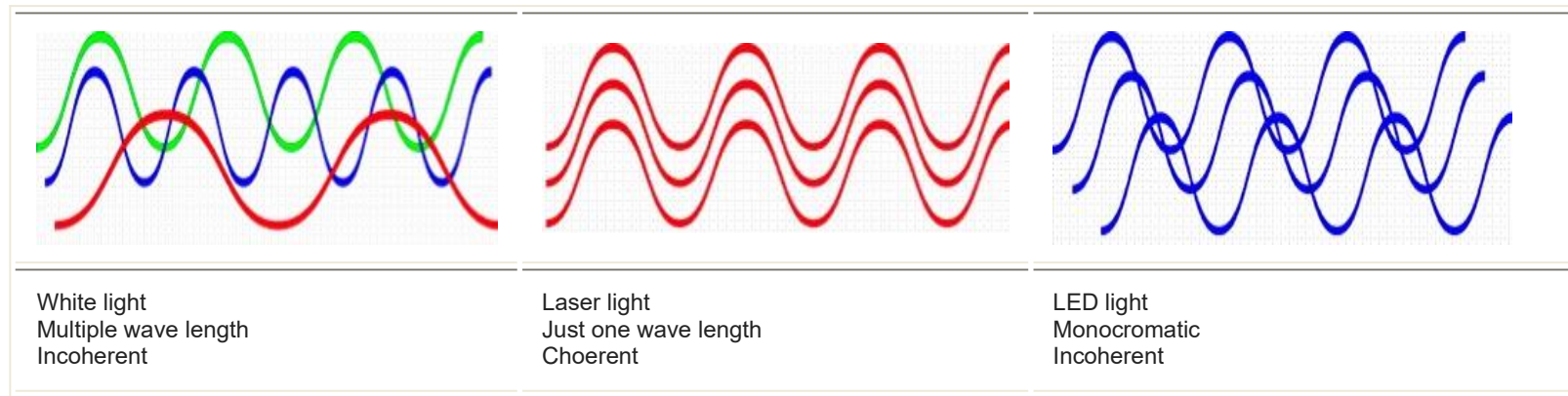


Fig.50. Types of lights and characteristics¹

There are several aspects of laser light that are often referred to in the literature, namely monochromaticity, coherence, and polarization. Monochromaticity is probably the most important factor, since many of the therapeutic effects have been noted in numerous studies of noncoherent light therapy. In addition, it is known that polarization is rapidly lost between tissues, and therefore may be less important than initially thought.

Terminology: Laser therapy falls into a category of laser light known as 3A or 3B and refers to mild to moderate laser sources. More recently, the terms Low Level Laser Therapy (LLLT) and Low Intensity Laser Therapy (LILT) have been adopted. Ohshiro & Calderhead suggest that LLLT involves treatment with doses that do not produce a detectable increase in the temperature of the treated tissues and no visible macroscopic changes in tissue structure. The energy can cause an increase in temperature and change the structure of tissues, but this is not the purpose of laser therapy, which is applied below the level at which such effects can be achieved (e.g. laser surgery).

¹ source: <http://www.electrotherapy.org/modality/laser-therapy>

11.2. Basic physical parameters in laser therapy

Most LLLT devices generate light in the visible red and near-infrared band of the light spectrum, with a wavelength of 600–1000 nm. The average power of these devices is generally low (1–100 mW), although the peak power can be much higher.

The treatment devices can be equipped with a single or multiple emitter. The beam from single probes is usually narrow (~1 mm–6 or 7 mm) at the source. A probe array will usually include both higher and lower power emitters of different wavelengths. The emission can be continuous or pulsed, with narrow pulse widths (in the nano or microsecond range), as well as a wide variety of pulse repetition rates from 2 Hz to several thousand Hz.

It appears that lower rates are more effective in acute conditions, while higher rates are more effective in chronic conditions.



Fig.51. Types of probes used in laser therapy

The basic physical parameters in laser therapy are:

* *wavelength*: - the laser, regardless of monochromatic radiation, has a single wavelength, expressed in nanometers (nm).

* *power*: - depending on the power, lasers are classified into high-power or thermal lasers (W, tens of W) and low-power, athermal lasers (mW).

- the use of an optical attachment or light condenser causes a power loss at the tip of the probe of ~10%

- the interposition of media between the probe and the treated region induces power loss (source - optical conductor - air).

* *frequency*: is measured in Hertz (Hz) and expresses the number of oscillations per second.

* *power density*: expresses the energy emitted per unit area and is expressed in Joule /cm² (j /cm²).11.3.

11.3. Types of laser

Depending on the source:

- * solid lasers: ruby laser,
- * liquid lasers: CO₂,
- * gas lasers: He - Ne,
- * semiconductor lasers: Ga-As; Ga-Al-As.

Depending on the wavelength:

- * blue lasers: 400 - 500 nm,
- * green lasers: 500 - 550 nm,
- * red lasers: 600 - 700 nm,
- * infrared lasers: 700 - 950 nm.

Depending on the operating mode:

- * continuous lasers,
- * pulsed or pulsed lasers,
- * modulated lasers.

Depending on the type of radiation:

- * convergent, point radiation,
- * divergent radiation.

Depending on use:

- * simple, pencil-type lasers,
- * pocket lasers,
- * tabletop lasers.

11.4. Mechanisms of action of athermic lasers

- * when in contact with the skin, the laser beam undergoes mainly two phenomena: the reflection phenomenon and the absorption phenomenon;
- * through the reflection phenomenon, part of the emitted energy is lost;
- * the absorbed energy is directly proportional to the wavelength of the monochromatic radiation and inversely proportional to the distance between the source and the skin;
- * the red light laser ($\lambda = 600 - 700$) loses 50% of its power after a penetration of 2-3 mm;
- * the infrared light laser ($\lambda = 700 - 950$ nm) loses 50% of its power after a penetration of 2-3 cm;
- * the main mechanisms of action of the athermal laser:
 - acceleration of microcirculation,
 - balancing the electric membrane potential of the cell,
 - stimulation of intracellular enzymatic activity (especially the Krebs cycle),

- improvement of circulation and peripheral oxygen utilization,
- improvement of glucose utilization,
- intensification of fibroblastic activity,
- activation of phagocytosis,
- activation of the Na/K membrane pump,
- improvement of intracellular Ca^{++} transport,
- local modulation of inflammatory mediators (prostaglandins, histamine, serotonin, etc.)

Absorption of light in tissues

As with any form of energy used in electrotherapy, it must be absorbed by the tissues to have an effect. Absorption of light energy in tissues is a complex phenomenon, but in general, short waves (ultraviolet) are the first to be absorbed in the epidermis by pigments, amino acids and nucleic acids.

Long waves ($>1300\text{nm}$) appear to be rapidly absorbed by water and therefore have limited tissue penetration. Bands between 600-1000nm are capable of penetrating beyond the superficial epidermis and are, at least in part, available for absorption by other biological tissues. Application of LLLT to tissues of the human body releases sufficient energy to perturb local electron orbits, thus leading to heat generation, initiation of chemical changes, breaking of chemical bonds and production of free radicals. These are considered to be the main mechanisms by which LLLT achieves its physiological and therapeutic effects, with the primary target being the cell membrane.

Although much of the laser energy is absorbed in superficial tissues, deeper or more distant effects also occur, probably as a secondary consequence of chemical mediators or a secondary transmission system, although there is little scientific evidence to support this.

It is often said that because laser light is monochromatic, polarized, and coherent, it is capable of deeper penetration than “normal” (noncoherent) light. The penetration depth is 3–7 mm for visible red light and 30–40 mm for infrared laser light, although 10–15 mm is considered a more realistic depth for human tissue. The fact that polarization appears to be lost in tissue will result in even less penetration. The penetration depth refers to the depth

of tissue to which 37% of the light from the surface is able to penetrate. A very small percentage of the light energy from the surface will be available 10 mm or deeper into the tissue.

11.5. Dose calculation

Scientific and practical evidence, as well as specific equipment suppliers, recommend that the dose delivered to a patient during treatment be based on energy density, rather than power or other dosages.

Energy density is measured in Joules/square centimeter (J/cm²). One of the major obstacles to the widespread use of this therapy is the difficulty of obtaining doses with currently available devices.

Few devices allow the practitioner to set the dose in J/cm². Some allow dosing in Joules, others in Watts or Watts/cm². Some devices offer the possibility of calculating the dose, while others require certain parameters to make these calculations, namely

- emitted power (Watts)
- irradiated area (cm²)
- time (seconds)

ENERGY DENSITY (J/cm²) = total amount of energy (J) / irradiated area (cm²)

TOTAL ENERGY (J) = Average Power (Watts) x Time (sec.)

AVERAGE POWER (Watts) = Peak Power (W) x Frequency (Hz) x Pulse Duration (sec)

Experts suggest that the energy density/treatment session should be in the range of 0.1 – 12.0 J/cm², although there are some recommendations that go up to 30 J/cm². In general, low doses will apply especially in the case of acute lesions, which appear to be more energy sensitive.

11.6. Effects of athermic laser therapy

Laser-tissue interaction

As with many other forms of energy applied to the patient under the generic term of electrotherapy, the primary effects are divided into thermal and nonthermal effects. LLLT is considered to be a form of nonthermal application of energy, although it must be considered that the application and absorption of energy in the body will lead to an increase in temperature, at some point. **Nonthermal**, in this context, refers to the non-accumulative nature of the thermal energy.

Photobioactivation is a term widely used in relation to LILT – and refers to the stimulation of various biological phenomena by the use of light energy, but without significant thermal changes. The terms photobiostimulation and photobiomodulation are also used. Many of the aspects of photobioactivation were proposed by Karu who reported and demonstrated several key factors. She stated in a paper published in 1987 that some biomolecules (DNA¹, RNA²) modify their activity in response to irradiation with low-intensity visible light, but that these molecules do not appear to absorb the activity directly.

The cell membrane appears to be the first to absorb the energy, which subsequently generates intracellular effects through a second messenger or cascade response. The magnitude of the response is determined at least in part by the state of the cells/tissues prior to irradiation, namely, “starved” cells are more photosensitive than “fed” ones.

The list of physiological effects at the cellular or more general level is very large, and this material presents a compilation of them from various specialized materials and research papers. This illustrates the amplitude and scope of the effects of photobioactivation by light stimulation.

¹ Deoxyribonucleic acid (DNA) = (in English: deoxyribonucleic acid, DNA). It is made up of organic molecules among the most complex. The substance is found in every cell of living beings and is essential for the identity of any organism, from *Euglena viridis*, the small unicellular being on the border between plants and animals, to *Homo sapiens sapiens*, the contemporary man.

² Ribonucleic acid = like DNA, a polynucleotide formed by the copolymerization of ribonucleotides. A ribonucleotide is made up of a nitrogenous base (adenine A, guanine G, uracil U and cytosine C), a pentose (D-2-deoxyribose) and a phosphate. In the RNA molecule, uracil replaces thymine.

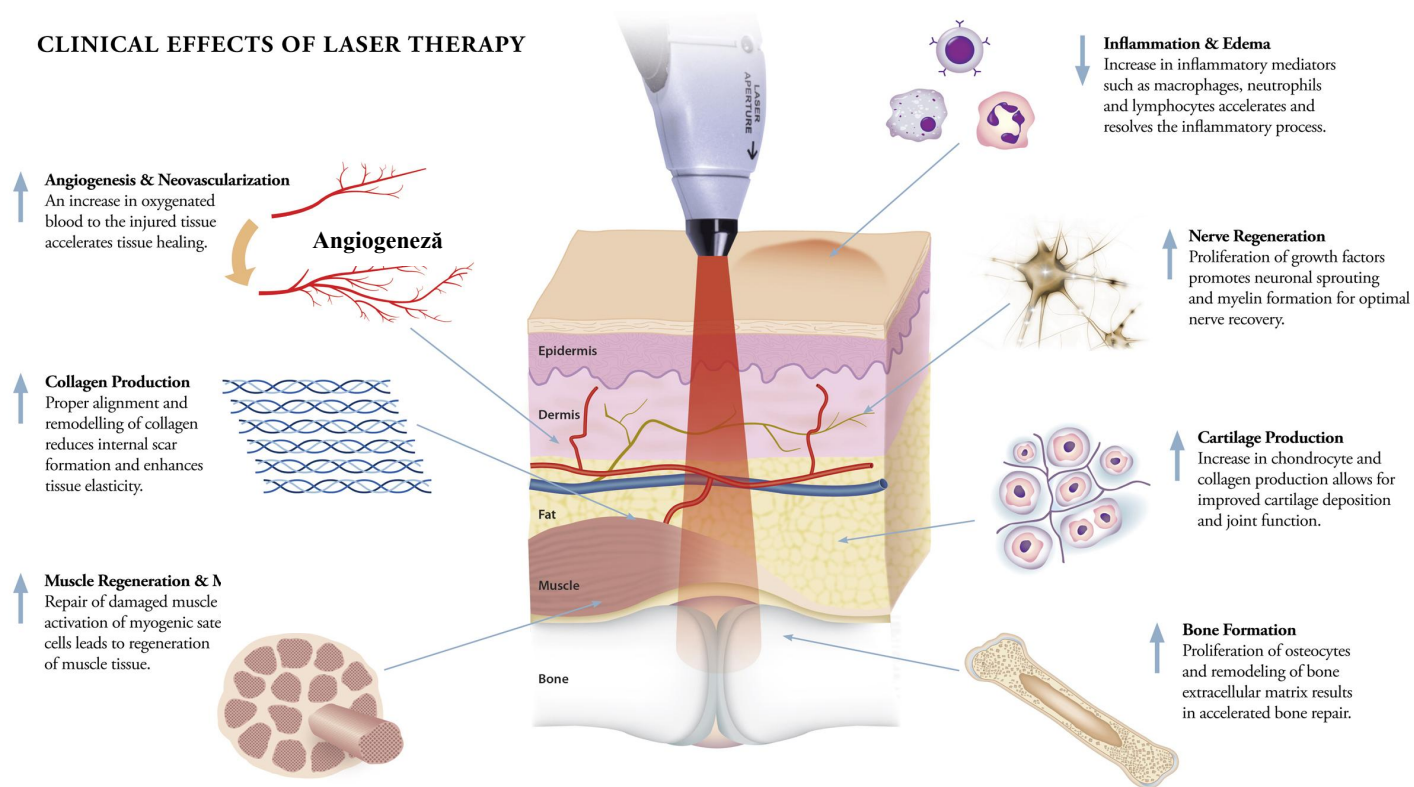


Fig.52. Clinical effects of LASER therapy¹

Effects of low-level laser therapy occur in all organs and tissues of the body, resulting in the restoration of proper cell function.

¹ source: <http://filosofi.ca/laser-therapy-centre/what-is-laser-therapy/>

These effects are listed below:

- *Analgesic*: pain reduction by stimulating the secretion of endorphins;
- *Anti-inflammatory*: inflammation reduction by reducing tissue excitability; disappearance of local pain, redness and heat;
- *Resorptive*: stopping the influx of fluids into the tissues;
- *Stimulation of lymphatic drainage*;
- *Trophic*: stimulation of blood circulation;
- *Increased flow of healing enzymes* in the traumatized area; a 75% increase in enzymes has been demonstrated
- *Stimulation of macrophages, activation of phagocytes*
- *Muscle relaxant*: reduction of spasm of contracted muscles (smooth and striated muscles), which led to the appearance of chronic pain, joint stiffness and reduced mobility;
- *Increase the bone healing process* by stimulating the proliferation of fibroblasts and osteoblasts;
- *Bactericidal, virucidal*: Stimulation of the immunological response by annihilating the pathological action of organisms such as: viruses, fungi, bacteria, parasites.

11.7. Clinical applications

Most laser devices use semiconductor diodes incorporated into the laser probe, which are connected to the control part of the device and which are applied to the patient.

- Laser:
- laser probe (has a single diode)
 - "shower" has 6 or 8 diodes
 - scanning system
 - microprocessor control part

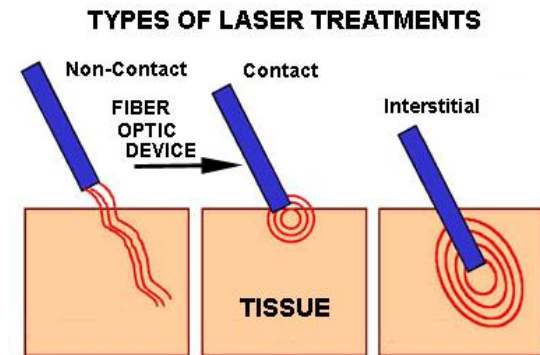


Fig.53. Types of LASER applications¹

¹ source: http://www.phoenix5.org/glossary/interstitial_laser_coagulation.html

The working parameters of the laser are chosen according to:

- the size of the area to be treated
- the depth at which the area to be treated is located in the tissue
- the type of pathology treated (acute, chronic).

Infrared lasers are used for deeper pathological processes. Red light lasers are used for wounds or other superficial pathologies. The wavelength of the laser beam is fixed.

The applied doses vary between $0.5 \div 4 \text{ J/cm}^2$ for acute lesions and $4 \div 50 \text{ J/cm}^2$ for chronic lesions. For deeper penetration, high powers are used ($> 100 \text{ mW}$). There are lasers that emit pulses, certain frequencies having special effects. Ex.: 10 mW laser

Laser sample with surface area of 0.12 cm^2 , power density of $10 \text{ mW}/0.125 \text{ cm}^2 = 80 \text{ mW/cm}^2$ and energy density (for 50 sec. of treatment) of $80 \text{ mW/cm}^2 \times 50 \text{ ms} = 4000 \text{ mJ/cm}^2 = 4 \text{ J/cm}^2$

Recent research, both laboratory and scientific, focuses on some key areas of treatment, the dominant ones being: wound healing, inflammatory arthropathies, soft tissue injuries and pain relief. However, the scientific evidence seems to be controversial.

Application technique

The patient is positioned comfortably, the area to be treated is exposed. The patient and the assistant wear protective glasses. The skin of the treatment area is cleaned with alcohol. The laser probe is applied in close contact with the skin, at the treatment point. The shower is applied at a short distance from the wound to be treated (or a scanning system is used).

Fig.54. Applications of athermic lasers¹



¹ source: <http://www.arikabrownchiropractic.com/cold-laser-therapy.html>

In practice, the power density, frequency, session duration, number of sessions are determined depending on the pathological process we want to treat. It is recommended:

- in acute forms, the power dose is 1 - 4 j/ cm²,
- in subacute forms, the power dose is 3 - 6 j/ cm²,
- in chronic forms, the power dose is 6 - 8 - 10 j/ cm².

Recommendations according to Dr. Claus:

Frequency	Affection
2,20 -----	Asthenia
2,45 -----	Edema
3,30 -----	HTN
4,90 -----	Stiff neck
6,80 -----	Muscle cramps
7,50 -----	Trigeminal neuralgia
7,70 -----	Spastic paralysis
8,25 -----	Flaccid paralysis
9,35 -----	Flaccid paralysis
9,50 -----	Migraine
9,60 -----	Rheumatic diseases
9,70 -----	Sciatica
10 -----	Phlebitis, leg ulcer

Recommendations according to Dr. Nogier:

Frequency	Effect
4.56 -----	trophic, resorptive
9.12 -----	analgesic
18.3 -----	metabolic stimulation
36.5 -----	sedative

Therapeutic indications of athermic lasers:

- * **traumatology:** fractures, muscle tears, established muscle hematomas, post-traumatic calcific myositis, sprains, dislocations, post-traumatic tendinitis, axonotmesis, burns
- * **dermatology:** acneiform dermatitis, eczema, herpes simplex, herpes zoster, psoriasis, varicose ulcers, bedsores, wounds
- * **soft tissue lesions**
- * **ENT:** tonsillitis, pharyngitis, sinusitis, tinnitus, otitis
- * **dentistry:** gingivitis, periodontitis, dental neuralgia, aphthous stomatitis.
- * **rheumatology:** rheumatoid arthritis, ankylosing spondylitis, arthrosis, tendonitis, bursitis
- * **non-articular rheumatism:** tendonitis, bursitis, periarthritis, myogelosis, fasciitis
- * **degenerative rheumatism:** arthrosis of various locations
- * **neurology:** trigeminal neuralgia, paresis, neuritis
- * **open wounds:** - treatment of ulcers, bedsores, wounds (a group probe is often used to cover the treated area, laser power usually up to 2 J/cm²; for the treatment of wound edges (periphery), single probes are used, laser power up to 4 J/cm²)
- * **pain** - practical evidence demonstrates that laser therapy has a more direct effect on nerve conduction, which will lead to pain reduction, as a more direct effect of this therapy.

11.8. Contraindications

A. Absolute contraindications:

- * direct irradiation of the eyeballs with the risk of inducing degenerative retinopathy,
- * irradiation of malignant or potentially malignant tumors,
- * febrile states.

B. Relative contraindications:

- * patients with mental disorders - epilepsy, neurotic syndromes
- * patients with cystic mastosis,

- * hyperthyroidism,
- * patients under steroid treatment,
- * pregnancy,
- * patients with implants cochlear, do not direct the laser beam towards the eye
- * tumors, areas of skin subjected to irradiation

12. LOW FREQUENCY MAGNETIC FIELD THERAPY

12.1. *Definition. Magnetic field.*

A magnetic field is produced by an electric current or an electric field. The magnetic field produced by an electric current has the same physical parameters as the generating electric current.

Magnetic field treatment has been used since the 16th century:

- Paracelsus – used magnets to stimulate fracture healing
- 1845 - Faraday discovers magnetism and the law of electromagnetic induction
- 1902 - the first studies on the biological effects of magnetic fields are published.

Magnetic fields are produced in coils through which electric current flows. The magnetic field can be (as well as the current that produces it):

- continuous
- pulsating

The intensity of the magnetic field - the density of the magnetic lines of force - is measured in T (tesla), in subunits mT (millitesla).

The Earth's magnetic field varies from about 60 mT at the poles to about 30 mT at the equator.

Studies in recent years have demonstrated the biological effects of pulsating (interrupted) magnetic fields in particular. Continuous magnetic fields do not have any adverse effects on the human body. The WHO allows the application of a continuous magnetic field of 2-3 T to the human body. A magnetic bracelet has 20-130 mT.

12.2. Mechanism of action of magnetic fields

The mechanism of action of magnetic fields on the body is not fully known; it is considered to be similar to that of electromagnetic radiation (short waves):

- production of energy changes at the level of cell membranes with increased membrane diffusion and increased cellular metabolism
- stimulation of vascular neoformation

- stimulation of the growth of granulation repair tissue at the level of wounds
- stimulation of collagen production at the level of cartilage
- stimulation of cellular oxidative enzymatic activity (cytochemistry oxidase, peroxidase) with better use of oxygen.

Beneficial effects of the magnetic field have been demonstrated on:

- ***central and vegetative nervous system***

- continuous magnetic field – sedative and parasympathetic effect
- interrupted magnetic field – excitatory and sympathicotonic effect
- frequencies below 10 Hz – vagotonic
- frequencies of 50 Hz – sympathicotonic

- ***blood and lymphatic circulation***

- the interrupted magnetic field stimulates the development of neoformation vessels and the kinetics of lymphatic vessels

- ***cellular metabolic processes***

- continuous magnetic fields stimulate anabolism
- interrupted magnetic fields stimulate catabolism

- ***neuromuscular system – especially phasic muscles***

- the continuous magnetic field increases the rhythmicity of discharges in the motor neuron with an increase in the recruitment phenomenon
- the interrupted magnetic field increases the contraction force of muscle fibers.

12.3. MAGNETODIAFLUX device

It is a Romanian product, consisting of a low-frequency magnetic field generator, three coils and related cables, having the following parameters:

- * frequency of 50 and 100 Hz,
- * fixed intensities: - 4 mT cervical coil,
 - 2 mT lumbar coil,
 - 20-23 mT localizer coil.

MAGNETODIAFLUX can generate low-frequency magnetic fields in the following ways:

I. Continuous form:

- * 50 Hz,
- * 100 Hz,
- * 50 - 100 Hz (6s with 50 Hz, followed without a break by 6s with 100 Hz)

II. Rhythmically interrupted form:

- * 50 Hz (3s 50 Hz, 3s pause, 3s 50 Hz etc.),
- * 100 Hz (3s 100 Hz, 3s pause, 3s 100 Hz etc.),
- * 50 - 100 Hz (3s 50 Hz, 3s pause, 3s 100 Hz, 3s pause etc.)

III. Arrhythmically interrupted form:

- * 50 Hz (variable periods of 50 Hz interspersed with pauses of variable durations that follow one another randomly),
- * 100 Hz (variable periods of 100 Hz interspersed with pauses of variable durations that follow one another randomly),
- * 50 - 100 Hz (6s with 50 Hz, 6s with 100 Hz, interspersed with uneven pauses that follow one another randomly).

12.4. Effects of low-frequency magnetic field therapy

A. Continuous unmodulated forms:

- * sedative effect,
- * sympatholytic effect,
- * trophotropic effect.

B. Interrupted forms:

- * excitatory effect,
- * sympathicotonic effect,
- * ergotropic effect.

The choice of application forms - continuous, interrupted, depends on the underlying condition, the constitutional type and individual neurovegetative reactivity and the subject's biorhythm.

Proven effects of magnetic fields are:

- * acceleration of fracture callus
- * stimulation of wound healing
- * sedation and analgesia
- * stimulation of microcirculation

12.5. Rules for applying treatment with low-frequency magnetic fields

- * treatment couch made of insulating material,
- * it is recommended that the patient remove metal objects from the body,
- * avoid placing the coils in the vicinity of any metal implants of the patient,
- * application of the treatment to patients with pacemakers is strictly prohibited,
- * the patient lies supine, loosely dressed,
- * the cephalic extremity facing north,
- * the arrow on the cervical and lumbar coil is oriented towards the cephalic extremity,
- * the locating coils are positioned according to the poles marked with the respective symbols N - S, on the treated region.

Application technique

- magnetic field devices have applicators that are placed on the areas to be treated or coils (cervical and lumbar) that are attached to a treatment bed
- the applicators or coils are applied over the patient's clothing
- modern devices can also be applied to areas with metal implants (interrupted magnetic fields)
- a distance of at least 1 m is indicated between magnetotherapy devices and other electrical devices (see manufacturers' instructions)

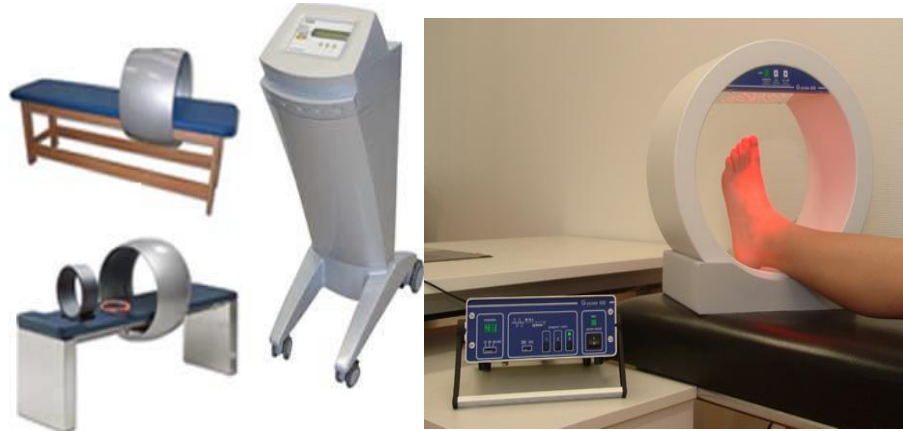


Fig.55. Treatment bed

12.6. Indications for low-frequency magnetic field therapy

A. Rheumatic diseases: chronic degenerative rheumatism, abarticular rheumatism (tendinitis, myalgia, myogelosis), inflammatory rheumatism (rheumatoid arthritis st. I and II, ankylosing spondylitis, psoriatic arthritis)

B. Post-traumatic sequelae: wounds, contusions, muscle hematomas, sprains, musculotendinous ruptures, post-fractures, fracture consolidation.

C. Neuropsychiatric diseases: neuroses, neurovegetative dystonias, hemiplegia, paraplegia, Parkinson's disease.

D. Cardiovascular diseases:

* functional peripheral vascular diseases: Raynaud's disease, Raynaud's syndrome, acrocyanosis

* organic peripheral vascular diseases: thrombophlebitis obliterans, atherosclerosis obliterans of the limbs, diabetic arteriopathy, cerebral atherosclerosis, arterial hypertension: mild and moderate form

* lymphedema stage I and II

E. Respiratory diseases: bronchial asthma, chronic bronchitis.

F. Digestive diseases: chronic gastritis, chronic gastroduodenal ulcers, biliary motility disorders.

G. Endocrine diseases: type II diabetes mellitus, hyperthyroidism.

H. Gynecological diseases: dysmenorrhea, chronic non-specific metroadnexitis, chronic non-specific cervicitis, climax and preclimax disorders.

I. Neurological diseases: spasticity after vascular accidents.

12.7. Contraindications of low-frequency magnetic field therapy

- * pacemaker wearers,
- * hypotensive syndromes,
- * advanced cerebral atherosclerosis,
- * hemorrhagic conditions, severe hematological diseases
- * anemia
- * malignant tumors
- * active pulmonary/extrapulmonary TB
- * infectious diseases, febrile conditions,
- * renal, hepatic, cardiac, pulmonary insufficiency,
- * psychosis, epilepsy,
- * pregnancy.

12.8. Principles of application of low-frequency magnetic field therapy

- * depending on the condition and the objectives pursued, both the form of application and the frequency of work are chosen,
- * the duration of the session varies depending on the disease and objectives: in principle tens of minutes (20 - 30 - 45 min.),
- * number of sessions: high (12 - 18 - 22)
- * application rate: daily.

13. TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION (TENS)

-Transcutaneous Electrical Nerve Stimulation -

13.1. Definition

Transcutaneous electrical nerve stimulation (TENS) uses low-frequency currents in the treatment of pain. TENS is an electrical stimulation method whose main purpose is to relieve symptomatic pain by exciting sensory nerves, thereby stimulating the pain control gate mechanisms and/or the opioid system.

The different ways of applying TENS depend on different physiological mechanisms. The effectiveness of TENS varies depending on the way of treating pain, but studies show that when used properly, TENS leads to a significant reduction in pain, in a way greater than the effect of a placebo intervention.

The term TENS refers to any electrical stimulation that uses electrodes applied to the skin, with the aim of achieving nerve stimulation. In a clinical context, it refers to the use of electrical stimulation with the specific aim of relieving symptomatic pain.

TENS is often applied using small, battery-operated devices. In some countries, these devices can be purchased over the counter, while in others, a prescription from a doctor or other healthcare professional is required. An example of a TENS device is illustrated below (Fig. 56).

In practice, most practitioners consider TENS as a treatment option for patients experiencing chronic pain (the literature provides evidence in this regard). More recently, specialized studies have demonstrated that TENS is a valid option for acute pain as well (Desantana et al, 2008; Sbruzzi et al, 2012; Silva et al, 2012; Solak et al, 2007 and Unterrainer et al, 2010).

As a treatment method, TENS is noninvasive and has few adverse effects, compared to analgesic drug therapy. The most common cause of allergic skin reactions (approximately 2-3% of patients) is the material from which the electrodes are made, the conductive gel or the electrode tape. Most of the electrodes used in TENS applications are self-adhesive, with gel, which offers several advantages such as: reducing the risk of non-specific infections, ease of application, low incidence of allergic phenomena, lower overall costs. Some TENS devices offer preset programs and automatic setting of treatment parameters.

13.2. TENS device parameters

Before describing how TENS can be used to relieve symptomatic pain, we will talk about the main variables used in the treatment offered by TENS devices. The figure below shows an example of this.

The current intensity (A - power) will have an amplitude between 0 - 80 mA, although some machines provide an output flow of up to 100 mA. Although we are talking about low intensity currents, they are sufficient, since the main target of the therapy is the sensory nerves, this current passing through the tissues is enough to depolarize the nerves.

The device will deliver discrete pulses of electrical energy, the rate of their discharge (pulse rate or frequency (B) varying from 1 or 2 pulses/sec. (pps), up to 200 or 250 pps (sometimes the term Hertz or Hz is used).¹

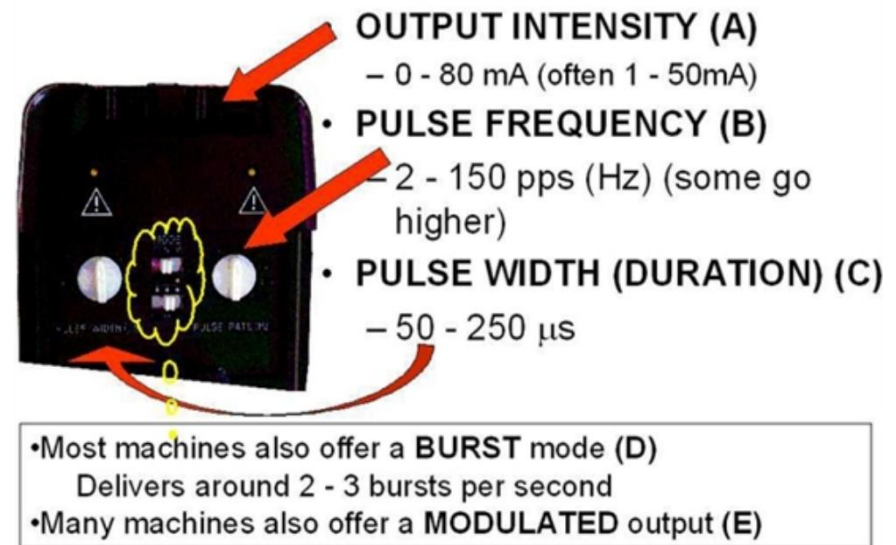


Fig.56. Variables provided by TENS devices²

To be clinically effective, it is recommended that the TENS device cover a range of 2–150 pps or Hz.

In addition to the stimulation rate, the duration (or width) of each pulse (C) can vary from 40 to 250 microseconds (ms – a microsecond is 1 millionth of a second). The most clinically effective duration is 200 ms.

The reason such a short pulse duration can be used to achieve these effects is that the target of stimulation is

¹Tim Watson(2013), Transcutaneous Electrical Nerve Stimulation, <http://www.electrotherapy.org/assets/Downloads/TENS%20April%202013.pdf>

² source: www.electrotherapy.org/assets/Downloads/TENS%20April%202013.pdf

sensory nerves, which have low stimulation thresholds (are easy to stimulate) and therefore respond by rapidly changing their electrical status.

In general, it is not necessary to apply a prolonged pulse to force depolarization of the sensory nerve, so stimulation of less than a millisecond is sufficient. In addition, modern devices offer a BURST¹ mode (D), in which pulses are delivered in trains of 2-3 bursts/sec.

A MODULATED option (E) may also be available, which involves a method by which the emitted pulse becomes irregular, thus avoiding the accommodation effects common with this type of stimulation.

Most devices offer two output channels, meaning that two pairs of electrodes can be used simultaneously. In some situations, this can be an advantage, although most patients and therapists tend to use only one application channel. Diffuse and large-area pain can be effectively treated with 4 electrodes (2 channels), and this system can be used as a treatment for local or referred pain.

The pulses delivered by TENS stimulators vary depending on the manufacturer, the most common being biphasic pulse waves. The biphasic nature of the pulse means that the diadynamic current component does not normally occur, thus reducing skin reactions due to the appearance of electrolytes under the electrodes.

13.3. Mechanisms of action

The type of stimulation provided by TENS devices aims to stimulate (excite) the sensory nerves, and thereby, activate specific natural pain relief mechanisms. It was assumed that there are two major mechanisms for pain reduction: the “pain gate” mechanism (see page 24) and the endogenous opioid system (see page 26), and therefore the variation of the parameters used in the stimulation will be considered.

Pain relief by activating the pain gate mechanism involves the activation (excitation) of sensitive A beta ($A\beta$) fibers, and implicitly reducing the transmission of the noxious stimulus from the “c” fibers, through the spinal cord, to the higher centers. $A\beta$ fibers seem to be stimulated at a relatively high rate (of the order of 80 – 130 Hz or pps). There is no single frequency that is right for everyone, but this range seems to cover most people. From a clinical

¹ explosion

perspective, it is important to find the optimal treatment frequency for each individual patient, which will certainly vary from person to person.

An alternative approach is to stimulate A delta ($A\delta$) fibers, which respond to a lower stimulation rate (on the order of 2–5 Hz, although some authors consider a range between 2–10 Hz), which will activate the endogenous opioid mechanism system, which will lead to pain reduction by releasing endogenous opiates (enkephalin) in the spinal cord and which will reduce the activation of sensory pathways transmitting noxious stimuli. A third possibility is to stimulate both types of nerve fibers simultaneously by using the BURST mode. In this case, the highest stimulation frequency (approx. 100 Hz) is interrupted (burst) 2–3 times per second.

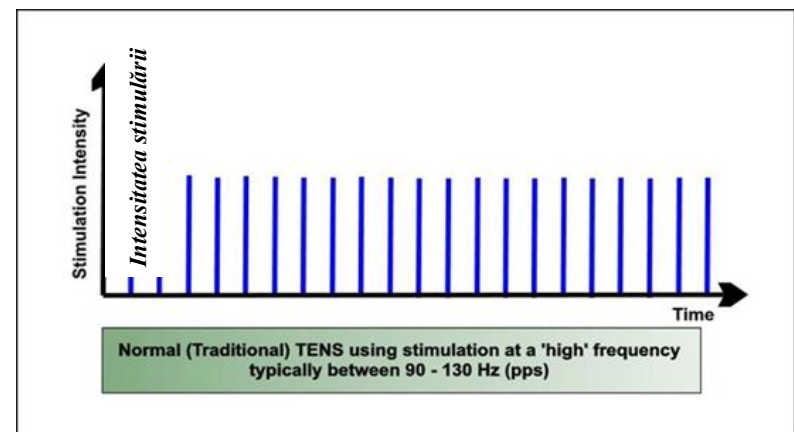
When the device is “on”, it will deliver 100 Hz pulses, stimulating the $A\beta$ fibers (hence the pain gate mechanism), but due to their interruption, each interruption will activate the $A\delta$ fibers (thus stimulating the endogenous opioid mechanism system).

For some patients this is by far the most effective way to approach pain therapy, although, as a sensation, many patients find it less acceptable than other forms of TENS, as the sensation created is of a “claw” nature and overlaps with that of muscle contraction caused by low or high frequency currents.

13.4. Types of TENS

13.4.1. Conventional TENS (*high TENS, normal TENS*)

Usually uses relatively high frequency stimulation (80 - 130Hz) and involves relatively narrow pulses (short duration) and therefore, in this situation, there is less possibility to manipulate the pulse width (duration), as shown in the literature. Most patients report that the best effects occur at a pulse duration of approx. 200ms.



Stimulation is provided at a 'normal' intensity. 30 minutes is probably the minimum effective time, but the session can last as long as necessary. Pain relief is obtained during the stimulation, the effect after the end of the treatment session being limited. Traditional TENS seems to be more effective in acute conditions and in the type of treatment period. Traditional TENS acts on A β fibers, triggering the pain control gate mechanism¹.

Conventional TENS (high frequency, low intensity)

- has a frequency between 50 ÷ 100 Hz
- pulse duration is < 150 μ s
- the duration of the procedure can be very long (even hours!)
- during application, the intensity is increased until a pleasant tingling sensation is obtained
- muscle contraction should not be obtained
- if muscle contractions occur during application, the muscle intensity is too high
- if the accommodation phenomenon occurs and the tingling sensation disappears, the current intensity will be slightly increased
- if it is necessary to use TENS for a longer time (for chronic pain e.g.) to avoid accommodation, pulse trains (Burst TENS) are used.

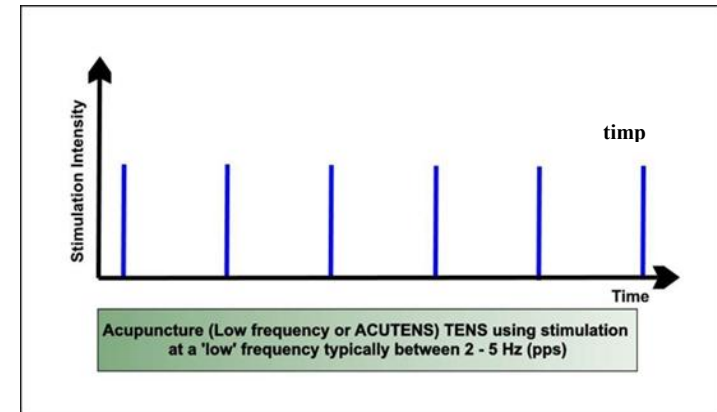
Ex.: 70 ms of conventional TENS followed by a pause of 430 ms (2 pulse trains/sec.)

It is used effectively to treat postoperative or post-scar pain, pain after nerve injuries, neuralgia, incarceration neuropathies, pain caused by the "phantom limb".

¹Tim Watson (2013), Transcutaneous Electrical Nerve Stimulation, <http://www.electrotherapy.org/assets/uploads/TENS%20April%202013.pdf>

13.4.2. Acupuncture TENS (Low-intensity TENS, AcuTENS)²

This type of TENS uses low-frequency stimulation (2-5Hz) with wide/long pulses (200-250ms). The intensity used will be higher than with traditional TENS – not yet at the patient's threshold of sensitivity, but it will produce a strong, well-defined sensation. The application time will be 30 minutes for a minimum effective dose. With this type of TENS stimulation, the opioid systems need time to take effect, and therefore pain relief may occur more slowly than with traditional methods. Once a sufficient amount of opioid has been released, the effect will persist for several hours after the stimulus has stopped. Many patients find that stimulating with this low frequency several times a day is an effective strategy. The effect after treatment can last up to several hours and varies from one patient to another.



The low-frequency stimulation of 2 – 5 Hz used in acupuncture TENS/ACUTENS acts on A δ fibers, triggering opioid pain-relieving mechanisms. Acupuncture TENS appears to be more effective in chronic conditions. The treatment can be used as often as needed (there is no time limit). The most commonly used stimulation/pause pattern is 1-2 h stimulation, followed by 1-2-h pause.

13.4.3. TENS Short Intense TENS

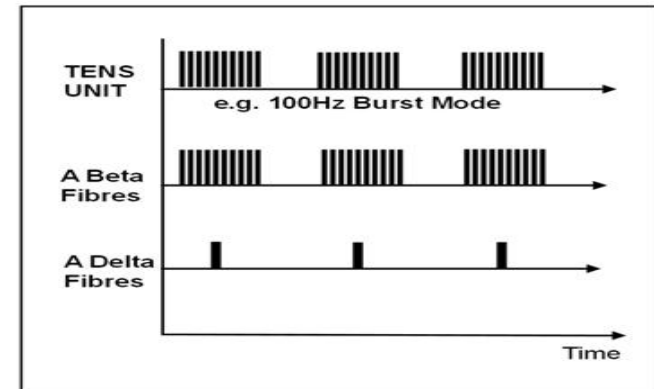
This is a mode of application of TENS used to obtain rapid pain relief, but some patients may find the stimulation too intense and will not tolerate it for long enough to be effective. The pulse frequency is high (in the 80-130Hz range), as is the pulse duration (200 ms pulse). The current is delivered at or near the patient's tolerance level – meaning that the patient no longer desires an increase in stimulus intensity. The energy delivered to the

patient is relatively high, compared to other therapeutic approaches. It is recommended that the treatment session be between 15 – 30 minutes, no more.

13.4.4. TENS BURST mode

As previously described, the device is set to deliver traditional TENS, with the BURST mode allowing the delivery of “bursts” at a rate of 2 – 3 times/sec. The stimulation intensity should be relatively high, but not as high as in the case of short intense TENS, but more like in the case of low intensity TENS.¹

Fig.59. TENS BURST mode (Watson 2013)



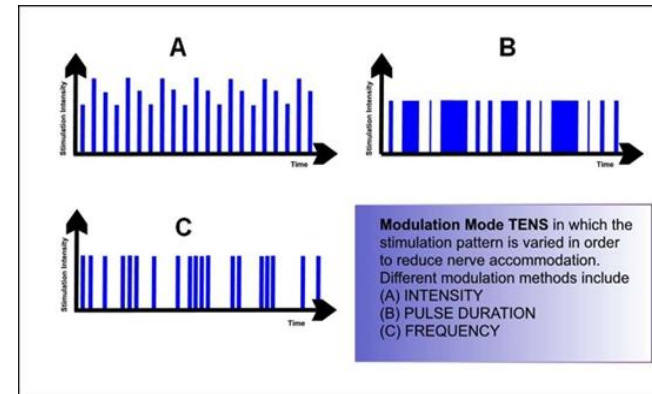
It is assumed that this mode of application can simultaneously stimulate both the pain control gate and the intrinsic opioid mechanisms. Figure 59 shows stimulation (at approx. 100 Hz) delivered in BURST mode (at 2 – 3 Hz), so that both fiber types, A beta (at 100 Hz) and A delta (at 2 – 3 Hz) are stimulated.

¹ Tim Watson (2013), Transcutaneous Electrical Nerve Stimulation, <http://www.electrotherapy.org/assets/Downloads/TENS%20April%202013.pdf>

13.4.5. TENS modul MODULARE ²

In TENS MODULATION mode, the device delivers a less regular TENS stimulation pattern, in an attempt to reduce or avoid the accommodation effects that occur with regular stimulation. The device offers different ways to vary the stimulation pattern – some vary the frequency, others vary the pulse duration, others its intensity, others offer the possibility to choose between these options.

Fig.60. TENS MODULATION mode



This type of stimulation is useful for patients who use TENS several times a day, or for long periods of time, simply because due to the reduction of accommodation effects, it is no longer necessary to adjust the intensity of the current.

Setting the frequency: The patient or therapist must identify the most effective frequency for each patient's pain, and manipulating the frequency of the stimulus seems to be the best way to achieve this. Patients who are told not to manipulate the frequency are unlikely to have optimal effects.

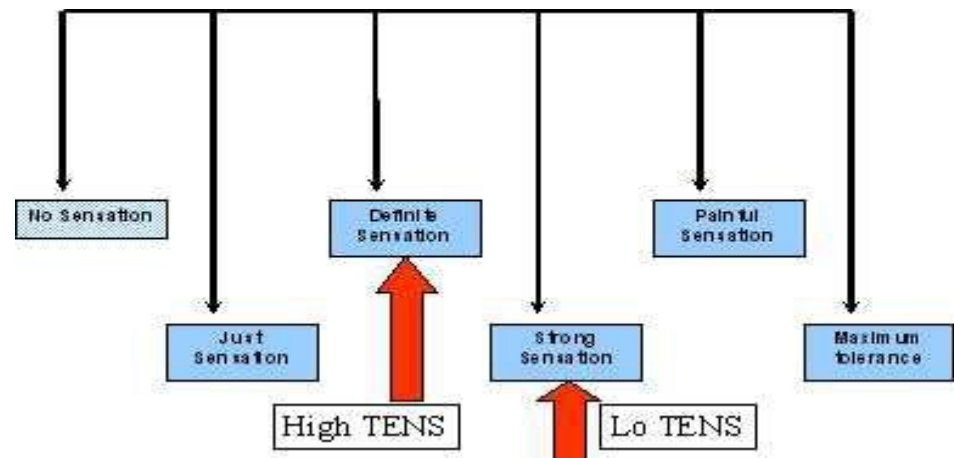


Fig.61. Setting the frequency and intensity of the stimulus (Watson 2013)

Stimulation intensity:

The most effective way to determine the intensity of the current seems to be related to what the patient feels during the stimulation, which varies from one session to another.

As a general indication, it is good to obtain a sensation of “certain presence but painless” for normal (high) TENS and a sensation of “strong but painless” for acupuncture mode (low intensity). Recent specialized studies demonstrate that a strong sensation, regardless of the chosen application mode, determines better clinical effects.¹

13.5. Example of good practice

13.5.1. Selection of TENS parameters

The selection of TENS parameters is made according to certain aspects.

a. type of pain: often, the patient’s symptoms will indicate the pulse frequency to be used in the treatment. For example, if the patient complains of acute soft tissue pain in the shoulder, a low-frequency current can exacerbate the symptoms by producing pulsatile contractions in the traumatized muscles.

b. electrode placement: if treating a bony area, avoid muscle tissue; do not use acupuncture TENS as muscle contractions are undesirable for this TENS modality

It is recommended to start treatment with conventional TENS. Many patients find the tingling sensation more comfortable than the muscle contraction caused by acupuncture TENS. Even if pain relief is obtained with conventional TENS, acupuncture TENS should be tried at least once during the course of treatment and any variation in the duration or degree of pain relief should be noted. It is good both conventional TENS and acupuncture should be tried, as significant differences may be observed in the same patient.

The TENS intensity should be increased gradually and the patient should be asked to report any sensation felt under the electrodes. The intensity should be increased until a “strong but comfortable” sensation is achieved. The patient should be warned that if the intensity is too high, the beneficial effects of the therapy will not be

¹ Tim Watson (2013), *Transcutaneous Electrical Nerve Stimulation*, <http://www.electrotherapy.org/assets/Downloads/TENS%20April%202013.pdf>

achieved. In acupuncture TENS applications, it is advisable to obtain muscle contraction but the patient must be able to tolerate the intensity.

13.5.2. Durata tratamentului

The first TENS treatment should be short (< 30 mins), to allow the patient to get used to the sensation and to allow the therapist to monitor for any adverse reactions, allergies to the electrodes, gel, tape, or to observe if the patient simply does not tolerate the electrostimulation.

After the initial treatment, TENS can be applied for up to one hour/session. A longer treatment period within the same session leads to skin irritation, which can be avoided by introducing half-hour breaks. Furthermore, when using acupuncture TENS, the patient will experience muscle contraction, and prolonged stimulation can lead to muscle fatigue. There are two situations in which TENS can be used continuously: labor pain and postoperative pain.

13.5.3. Electrode placement

It is essential to obtain information regarding the medical history and diagnosis of the pain before starting treatment. If the patient is taking analgesic medication, the first TENS session should be performed after the effects of the medication have worn off, in order not to confuse the effects of the medication with those of the TENS application and to be classified as a positive response to the treatment.

Placing the electrodes on either side of the lesion or painful area is the most common technique.

However, there are other alternatives that have been studied and proven effective – most of them are based on the appropriate stimulation of the nerve root level:

Peripheral nerve stimulation (near the painful area)

Motor point stimulation (innervated by the same nerve root)

Trigger or acupuncture point/point stimulation

Dermatome stimulation (see appendix 3), myotome stimulation¹ (see appendix 4).²

¹ Area of skin corresponding to the branches of a spinal nerve (Medical Dictionary, 1986)

If the source of pain is vague, diffuse or extensive, a double application can be made, one for local pain, the other for referred pain. Acupuncture TENS is effective when applied to the contralateral side of the body.

One of the main factors responsible for a poor response is ineffective electrode placement. The therapist should try several locations before deciding on the optimal one.

Essentially, there are four main categories of anatomical areas where TENS electrodes can be applied: painful areas, peripheral nerves, spinal nerve roots, specific points (acupuncture, motor and trigger points).

Regardless of the anatomical area where the electrodes are placed, electrical stimulation will result in the transmission of relevant information to the central nervous system. In any of the variants chosen, appropriate anatomical knowledge is required to obtain effective stimulation.

I. Applications on the painful area

Positioning the electrodes over or near the painful area is the most commonly used method. Since it is desired to obtain a paresthesia of the affected area, the electrodes will be placed at the proximal and distal edges of the affected area. If sensation is diminished or absent, the electrodes can be placed proximal to the affected area (on the normally innervated skin) to stimulate the sensory nerve afferents that reach the spinal cord from the affected area. In some situations, the application of the electrodes on the affected area proves to be uncomfortable for the patient (e.g. hypersensitivity as a result of peripheral nerve damage). In these situations, it is advisable to place the electrodes proximal to the hypersensitive area.

II. Peripheral Nerve Applications

Electrodes can be placed over peripheral nerves that have a cutaneous distribution in the affected area. For example, pain experienced on the dorsal aspect of the medial aspect of the hand and fingers I and II can be treated with electrodes placed over the superficial radial nerve along its course on the lateral aspect of the lower third of the forearm.

² Muscle group innervated by a single spinal nerve (the muscle and the nerve that innervates it form the myotome)

III. Spinal Nerve Roots

Thirty-one pairs of spinal nerves exit the spine through the intervertebral foramen. Each spinal nerve is formed by the union of the ventral (motor) and dorsal (sensory) roots at the intervertebral foramen, forming a mixed spinal nerve.

Placing the electrodes parallel to the spine (paraspinal application) and over the intervertebral foramen will allow stimulation of the corresponding spinal nerve root that innervates the affected dermatome.

IV. Acupuncture, Motor and Trigger Points

The last way to place electrodes is represented by a group of specific points: acupuncture, motor and trigger points. A motor unit is the entry point of the motor nerve into the muscle and is characterized by high electrical conductivity and low skin resistance.

Motor points are used for optimal muscle stimulation, therefore they can be considered as electrode application points for acupuncture TENS, when it is desired to trigger muscle contraction.

Trigger points are areas of contracture that are tense when palpated and cause referred pain.

In contrast, acupuncture points are well defined by traditional Chinese medicine, and can be stimulated to treat various conditions.

The choice of electrode application area depends on the correct assessment of the cause and location of the pain and the type of TENS chosen for treatment. If conventional TENS is used, the desired sensation is that of comfortable paresthesia, therefore it must be considered that the electrodes will not be placed on a bony area (malleoli) because they produce unwanted sensations for the patient. When using TENS acupuncture, it is advisable to obtain muscle contraction, therefore the electrodes will be placed above the muscle in relation to the painful area (you can use myotomes or corresponding motor points).

13.5.4. Types of electrodes

Self-adhesive and carbon electrodes are the most common types of electrodes. They are used together with a hydrogel, with or without a fixation tape. Self-adhesive electrodes are available in a wide variety of shapes and sizes, which allows the application of TENS in a wide variety of painful conditions. The main factor considered in the choice of electrodes is the allergic response, cost, ease of application and availability.

Application and fixation of electrodes. Self-adhesive electrodes are the easiest to apply. If hydrogel is used, it should be considered that its application will exceed the edges of the electrode. The presence of air under the electrodes should be avoided. The electrode-skin contact should be as uniform as possible, to ensure uniform current distribution. If a microporous tape is used to secure the rubber electrodes, it is important that the tape attachment area (Velcro area) covers the electrodes completely.

It is important to know that the distance between the electrodes will affect both the current density and the depth of current penetration into the tissues. Current density decreases with distance between the electrodes, due to the high electrical impedance of deep tissues. If the distance between the electrodes decreases, the current density in the area delimited by the electrodes will increase, and the depth of penetration is reduced. If the distance between the electrodes is large, the current density decreases and the depth of penetration increases.

Anode and Cathode Position

The patient will generally feel a stronger sensation under the cathode (the red electrode) compared to the anode – because the cathode is the active electrode. As a general rule, the cathode should be positioned close to the spine. In the case of applying TENS in acupuncture mode or on a motor point, the cathode will be positioned near or over that specific point.

APPLICATION TECHNIQUE

The patient is positioned and the area to be treated is exposed

- Skin integrity and the presence of local skin sensitivity are checked
- The parameters of the current to be applied to the device are set:
 1. for severe pain: - longer pulses
 - higher frequencies with modulation in pulse trains
 - higher current intensities
 2. for moderate or mild pain: - short pulses
 - both high and low frequencies
 - lower intensity
- The operation of the device is tested by the therapist.
- Attach the electrodes to the patient:
 1. disposable (self-adhesive) - the safest
 2. vacuum electrodes
- The electrodes are placed as close as possible to the painful area (one of them) and the other in the same dermatome or on the nerve trunk of the afferent nerve
 - One electrode can be placed on the painful area and one paraspinal, on the corresponding spinal area
 - 2 paraspinal electrodes can also be placed on the affected side, on the respective spinal nerve
 - The most effective positioning of the electrodes can be palpated
 - Electrodes are not placed on areas with tactile sensitivity disorders
 - Electrode size - the electrodes must be large:
 1. to avoid high current densities, with the risk of burns
 2. to ensure effective stimulation
- At the end of the procedure, the device is turned off, the skin is inspected for any skin lesions, then the electrodes are cleaned and disinfected
- The duration of therapy is guided by the clinical results obtained

13.6. Common problems and their solutions

Skin irritation: the cause of the irritation should be determined (e.g. allergic reaction to electrodes/tape/gel or prolonged TENS application). It is important to allow the skin to heal before reapplying an electrode to irritated skin. While the skin is healing, the electrode should be applied elsewhere, e.g. on a peripheral nerve or nerve root.

If the user is allergic to electrodes, another type should be tried. Many manufacturers offer hypoallergenic electrodes. After each TENS application, the skin will be allowed to breathe for one hour (this means the electrodes must be completely removed).

No pain relief: There are many people who do not respond to TENS, but it is important to try different TENS modes and electrode placements before determining that a user is not responding to treatment. It is important to compare the results obtained with conventional TENS applications and the acupuncture mode.

If acupuncture TENS is not tolerated

Some individuals do not tolerate the high intensity required to produce visible muscle contractions, which is used with acupuncture TENS applications. In this case, they will switch to the Burst application mode.

13.7. Indications

- low back pain, acute and chronic lumbago, sciatica, cervical pain
- knee osteoarthritis, rheumatoid arthritis
- post-surgical, post-traumatic pain
- neurogenic pain (diabetic neuropathy or trigeminal neuralgia)
- joint pain: hip, knee, ankle, foot, shoulder, elbow, fist, hand
- symptomatic relief of severe chronic pain
- increased circulation in the treatment area
- treatment of muscle cramps, muscle strains, ligament disorders
- postoperative muscle stimulation to avoid thrombosis
- prevention of muscle loss
- bursitis

- postherpetic neuralgia
- menstrual pain
- phantom pain of the amputated limb
- soft tissue injuries: contusions, sprains, dislocations
- tendonitis (tennis elbow), tendinosis, tendinopathies.

Examples of TENS applications can be found in ANNEXES 1, 2.

13.8. Contraindications

It is essential that before starting TENS treatment, information is obtained regarding possible contraindications. There are only a few contraindications for TENS, namely:

- patients who do not understand the therapist's instructions or are unable to cooperate.
- application of electrodes on the trunk, abdomen or pelvis during pregnancy: this generally refers to the placement of electrodes over the pregnant uterus; some sources recommend avoiding the use of TENS on any painful area during pregnancy, although no incidents have been reported so far. In conclusion, it is prudent not to place electrodes on the trunk, abdomen or uterus during the first trimester of pregnancy. TENS electrodes should not be placed on the pregnant uterus unless TENS is used for labor pains.
- patients with pacemakers: TENS interferes with certain types of cardiac pacemakers. Therefore, if TENS is applied to these patients, the therapist will consult with the patient's cardiologist before starting the treatment. It is advisable that the first session be done under EKG/Holter monitoring.
- patients with allergic response to electrodes, gel or fixation tape: if the patient has an allergic reaction to electrodes, gel or tape, this will be observed from the first session. If this incident occurs, the therapist will change the electrode, gel, tape with another type that does not cause allergic reactions, if possible.
- dermatological lesions, dermatitis, eczema.

- applications on the anterior aspects of the neck or on the carotid sinus: stimulation of this area can lead to a sudden drop in blood pressure. The carotid sinuses are located at the origin of the internal carotid arteries; they contain baroreceptors that detect changes in blood pressure.

- lack of normal skin sensations: a simple test (pinching/pinch) can demonstrate whether the skin innervation is intact. The danger of placing electrodes on skin with poor sensations can lead to skin irritation, burns. We must also remember that the treatment will be ineffective if adequate stimulation of the nerve afferents does not occur. If sensation is absent in a certain area, the electrodes can be placed in an area with intact sensitivity.

- patients with epilepsy: caution is indicated.

- eye applications and applications on the epiphyseal regions in children

14. NEUROMUSCULAR ELECTRICAL STIMULATION

14.1. Definition

Neuromuscular electrical stimulation (NMES), also known as muscle electrical stimulation (MSS) or electromyostimulation, is the triggering of muscle contraction using electrical impulses.

The impulses are generated by a device and delivered via electrodes placed on the skin to the muscle to be stimulated. The impulses mimic the action potential initiated by the central nervous system and which causes muscle contraction. Plate electrodes are usually used, firmly fixed to the skin.

NMS is both a form of electrotherapy and a form of muscle training. It is considered to be a complementary technique to sports training, an idea supported by scientific research in the field.

NMS causes muscle fiber adaptation (training). Due to the characteristics of skeletal muscle fibers, different types of fibers can be activated differently by different types of ESM, and the changes induced depend on the protocols or programs of application of ESNM. Some programs increase resistance, others increase strength.

In medicine, ESNM is used for rehabilitation purposes, such as in the prevention of atrophy of immobilized muscles as a result of musculoskeletal, bone, joint, ligament or tendon injuries.

NOTE! Neuromuscular electrical stimulation (NES) should not be confused with transcutaneous electrical stimulation (TENS), which is used in pain therapy. NMS stimulates the motor nerve to achieve muscle contraction, while TENS stimulates the sensory nerve endings in the skin to reduce pain.

For rehabilitation purposes, NES is usually used in combination with other physiotherapy methods and techniques. Its purpose is to stimulate the motor nerves with electrical impulses, since they are a natural component of the communication system between the brain and the muscular system. With the help of this therapy, these natural impulses are stimulated, thus favoring the regaining of muscle function.

14.2. Effects of neuromuscular electrical stimulation

As an adjunct to traditional physiotherapy, ESNM of healthy muscle has the role of:

- to tone, prevent or maintain muscle mass during periods of forced inactivity
 - to maintain joint mobility – it is applied in reducing the amplitude of movement as a result of surgical interventions, arthroscopy (shoulder, knee), or after immobilization following fractures
 - to facilitate voluntary muscle control
 - to temporarily reduce spasticity (which may be the result of chronic neuromuscular diseases, such as cerebral palsy, spina bifida, congenital clubfoot, some non-progressive myopathies).
 - muscle contraction-relaxation is effective in treating musculoskeletal and vascular diseases. Benefits also include: muscle relaxation, stimulation of local circulation, treatment of muscle stiffness and spasms
 - spastic muscle relaxation – electrostimulation is used to exhaust spastic muscle
 - muscle re-education: practical evidence demonstrates that physical exercise combined with electrical stimulation gives very good results in toning atrophied muscle.
- to increase local blood circulation: repeated rhythmic contractions lead to improved circulation, thus also contributing to the reduction of local edema.
- to prevent venous thrombosis by immediate postsurgical stimulation of the calf muscles: the use of ESNM to stimulate local circulation helps prevent venous thrombosis.

14.3. Physiology of the effects of therapeutic neuromuscular electrical stimulation

When an electrical stimulus is applied to the neuromuscular junction (the junction between the myelinated nerve fiber endings and the muscle fibers), the response of a single motor unit to the action of a single action potential or impulse is translated into a muscle contraction. If a second impulse is received before the motor unit relaxes, the motor unit will produce a new muscle contraction that fuses with the previous contraction. This phenomenon is called summed or fused contractions. If a train of impulses are received at a sufficient frequency for a certain type of motor unit, the summed contractions are transformed into a light (smooth) tetanic contraction.

Striated muscles in the human body are composed of two types of fibers:

- **Type I** – produce slow contractions, are slow oxidative muscle fibers, which have high resistance (e.g. this type of fiber is developed by distance runners)
- **Type II** – produce fast contractions, are glycolytic, which gives them the ability to provide bursts of intense energy for short periods of time (e.g. this type of fiber is developed by sprinters).

Fall and Lindstrom (1991) discuss the effects of applying different electrical frequencies on fast and slow muscle fibers. They argue that:

- slow fibers respond best to frequencies of 10–20 Hz, and
- fast fibers respond best to frequencies of 30–60 Hz.

These parameters are used for the striated muscles of the pelvic floor, which are composed of approximately 70% slow fibers and 30% fast fibers (Gilpin et al, 1989).

According to Laycock and Vodusek (2002), if high frequencies are used, for example above 40 Hz, fast muscle fibers will not relax between pulses and will produce a tetanic contraction. If a high frequency is maintained for a few seconds, it will cause fatigue of the fast muscle fibers.

Consequently, most muscle stimulation programs use cycles with pauses to allow motor unit recovery, and it is recommended that frequencies not exceed 40 – 50 Hz. (Herbert et al., 2012)

14.4. Therapeutic indications

Neuromuscular electrical stimulation is applied only if the muscle innervation is intact (including the brain, spinal cord, peripheral nerves), being a treatment indication for:

- Muscle toning or retraining of atrophied muscle as a result of immobilization, surgical interventions, injuries
- Other non-neurological conditions that cause muscle atrophy
- Dysphagia: stimulation of swallowing
- After a stroke: reduction of spasticity

- Hypotonia and muscle hypotrophy following prolonged immobilization
- Prevention of venous thrombosis
- Circulatory disorders
- Contractures due to burn scars
- Major knee surgeries
- Recent hip arthroplasty (ESNM is used until the start of physiotherapy)
- Reduction of edema
- Pain control
- Treatment for wounds and ulcers is still experimental

14.5. Contraindications and precautions

Contraindications

- Acute inflammations: perineum, vagina, anus
- Pacemaker
- Pregnancy
- Excessive vaginal bleeding
- Severe atrophic vaginitis
- Sensitivity disorders (internal/external)
- Pelvic malignancies
- Inability to understand or tolerate treatment

Precautions

- Immediately postpartum
- Skin conditions
- Diminished internal or external sensitivity
- Previous malignancy
- Piercing
- Intrauterine devices
- Hemophilia
- Epilepsy
- Sexual abuse

14.6. Example of good practice

ESNM uses low-frequency currents adjusted to stimulate the motor nerve of a muscle, with an intensity high enough to produce muscle contraction and to influence the muscle in depth.

In therapy, this technique is used by the therapist as a form of recovery after a stroke or other incidents that lead to loss of muscle function.

The therapy involves:

- applying electrodes to the area to be treated and fixing them appropriately;
- applications can be made on any segment where a feeling of discomfort, pain, weakness occurs
- generally, only two electrodes are used, but if it is desired to treat several areas simultaneously, two sets of electrodes will be used
- the session begins with low intensity and low frequency, then gradually increases to the patient's tolerance threshold (the treatment should be a pleasant, comfortable experience)
- when the electrical impulses are started, the patient will feel a slight tingling sensation which then turns into a massage sensation, as the frequency increases.
- if the intensity is too high, the patient will feel their muscles tense and contracted (ask the patient to signal this and ask the therapist to reduce the intensity/frequency).
- duration of sessions – you can start with 5-minute durations that are progressively increased up to 30 minutes/session.

ESNM can be used for the following purposes:

- Muscle toning: as in any repetitive exercise, there will be an increase in muscle mass and strength. This will lead to an increase in capillary density, to improved local circulation and, implicitly, to an improvement in the condition of the skin.
Increased joint mobility

- Electrical stimulation allows for regular stretching similar to passive stretching, but performed over a longer period of time. Special attention will be paid to joints that do not stretch excessively when trying to increase the mobility of others.

For example, it is sometimes useful to use an extension-blocking splint in the metacarpophalangeal joints to protect them and to increase the effectiveness of the electrical impulses on the proximal and distal interphalangeal joints.

Another example may be the use of a flexion-blocking splint in the wrist joint when practicing finger flexion.

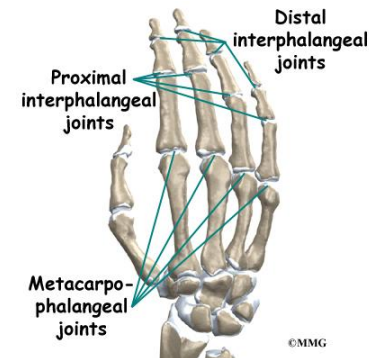
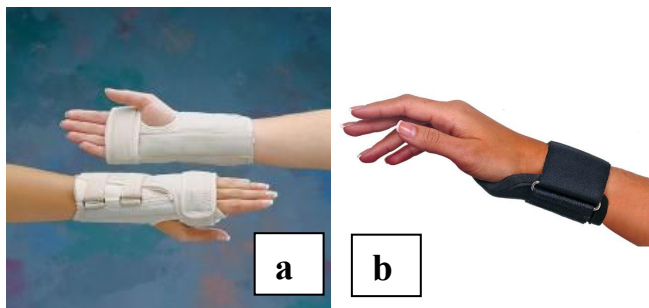


Fig.62. Hand joints¹



*Fig. 63a) Extension blocking splint in the MCF joint²
63b) Flexion blocking splint in the MCF joint³*

Relaxation of spastic muscles

When a muscle contracts, the activity of the muscle spindles relies on that of inhibitory interneurons, which in turn inhibit the motor neurons of the antagonist muscle, reducing its activity. This mechanism is known as reciprocal inhibition and its effect can be exploited by stimulating the antagonist of the spastic muscle.

¹ source: <http://www.eorthopod.com/content/pip-joint-injuries-finger>

² source: <http://www.themobilitysuperstore.co.uk/category/222/arthritis-&-hand-positioning-splints>, accessed 27.02.2014

³ source: <http://www.colonialmedical.com/carpal-mate-wrist-splint-P-1481.html>, accessed 27.02.2014

Like the Ia afferents, the nerves that pass from the neuromuscular spindles to the spine and the inhibitory interneurons have a large diameter and therefore require a low level of stimulation, so they will always be excited, even if the stimulation produces only a slight contraction.

Usually, after training the antagonist of the spastic muscle there is a period of reduced spasticity that can last from a few minutes to a few hours. By repeating these exercises, synaptic connections can be strengthened through long-term potentiation and spasticity will be reduced for a longer time. Studies show that treatments must be performed for a long time to have continuous therapeutic effects.

It has been shown that stimulation of the spastic muscle has a relaxing effect. This is due to antidromic¹ stimulation of motor neurons, which means that the stimulation directs the nerve impulse to be transmitted from the nerve to the spinal cord, acting on Renshaw interneurons. These have an inhibitory effect on α -motoneurons, reducing their excitability and therefore reducing spasticity.

Reciprocal stimulation of the agonist-antagonist pair can be effective in reducing spasticity. There are, however, some reservations in that toning the spastic muscle may cause the subsequent return of an even greater degree of spasticity. Therefore, it is advisable to resort to antagonist stimulation only. Agonist stimulation should only be performed if toning and retraining the spastic muscle is a goal of the treatment.

Movement Reeducation

When muscle contraction is produced by electrical stimulation, a variety of sensory inputs are produced. These include direct sensation caused by the stimulation and proprioceptive feedback from joints, tendons, muscles and mechanoreceptors. There will also be antidromic stimulation of α (alpha) and γ (gamma) motoneurons. All of this will cause a significant increase in the activity of the nerve pathways to the cortex and at centers, thus stimulating the formation of new synaptic connections. The excitation of Ia afferents has the same effect as the

¹ Antidromic stimulation = the impulse at the level of the axon that refers to its transmission in the opposite direction to the normal (orthodromic) one. Thus, the impulse is transmitted along the axon, from the neuronal terminal towards the neuronal body. For most neurons, the dendrites, body and axons depolarize, forming an action potential that is transmitted from the point of generation of the depolarization (near the cell body) along the neuronal axon. Antidromic activation is often induced experimentally by direct electrical stimulation of a pre-established structure. (<http://en.wikipedia.org/wiki/Antidromic>)

activation of neuromuscular spindles by stretching, which will cause excitation of the motor neuron and then muscle contraction.

This increased level of motor neuron excitation will allow even weaker descending motor neuron impulses to activate the motor neuron and produce voluntary muscle contraction. It is important that the patient is asked to perform voluntary movements simultaneously with the action of the electrical stimulus, in order to increase the effect. This voluntary effect should not be so great as to increase spasticity and inhibit the desired movements.

Strengthening the effect of botulinum toxin¹

This can be achieved in two ways:

- It has been shown that botulinum toxin is more easily assimilated by receptors if the muscle is active. This can be achieved by directly stimulating the target muscle or by exercising the antagonist muscle, which will lead to the triggering of the stretch reflex in the target muscle. The effect of the toxin administration occurs two days after administration.
- The second method is to use electrical stimulation to help relearn movement, during the three months of respite until spasticity returns.

Improved sensory perception

Sensory input will promote the formation of new synaptic connections in the sensory cortex and thus improve sensory perception or awareness. Specialized studies have demonstrated improved sensitivity, illustrated by the reduction of the discrimination distance between two points on the skin and the reduction of neglect syndrome.

¹ Botulinum toxin is a protein produced by the bacterium *Clostridium botulinum*. To understand its effect, it is necessary to understand the mechanism of muscle function. The brain sends messages to the muscles to make them contract and move. These messages first reach the spinal cord and through the peripheral nerves to the muscles. Acetylcholine transmits this message from the nerve to the muscle. Pathologies in the brain or spinal cord can lead to the appearance of exaggerated or uncoordinated messages to the muscles. They become spastic, often causing pain. Botulinum toxin prevents the discharge of acetylcholine from the nerve endings to the muscles, thus blocking the abnormal command from the brain. This reduces muscle spasm, abnormal postures, as well as the associated pain. The art of botulinum toxin injections lies in the correct selection of muscles and establishing the appropriate dose, which reduces muscle spasms without causing complete paralysis. The effect of botulinum toxin begins in 2-14 days and lasts on average for almost three months. It requires reinjection to maintain the effect.

14.6.1. ESNM Applications for the Hemiplegic Upper Limb

Subluxația umărului

Shoulder Subluxation

Subluxation occurs when the muscle tone around the shoulder joint is reduced, leading to a loss of continuity at the glenohumeral joint. The tissues around the sleeve stretch and pain and functional impairment are common problems. Often, when spasticity follows a period of flaccid paralysis, muscle tone will not be balanced, and hyperactivity of the pectoral muscles will pull the humerus into internal rotation.

The muscles around the shoulder joint can be divided into two groups:

- The group of muscles whose main role is to maintain the humeral head in the socket (supraspinous and teres minor, etc.)
- The group of muscles that play a role in the movement of the entire limb (e.g. deltoid, pectoralis, etc.) The deltoid is easy to stimulate, being the most superficial muscle; It is also useful in reaching the supraspinatus, as its central role is to fix the humeral head.

If there is no internal rotation, one electrode is placed on the middle deltoid and the second above the supraspinatus muscle. The choice of the active electrode is made depending on which one wants to have the stronger action. For example, if the active electrode placed on the deltoid will produce too much abduction, the polarity is reversed. If the arm is internally rotated, the active electrode will be placed on the posterior deltoid. If greater external rotation is required, stimulation of the teres minor and infraspinatus can be tried. Stimulation of the supraspinatus muscle can be difficult without activating the trapezius, which will lead to elevation of the shoulder girdle. In this case, it is more advisable to stimulate the middle and posterior deltoid. Two stimulation channels can be used, alternating the position of the electrodes.

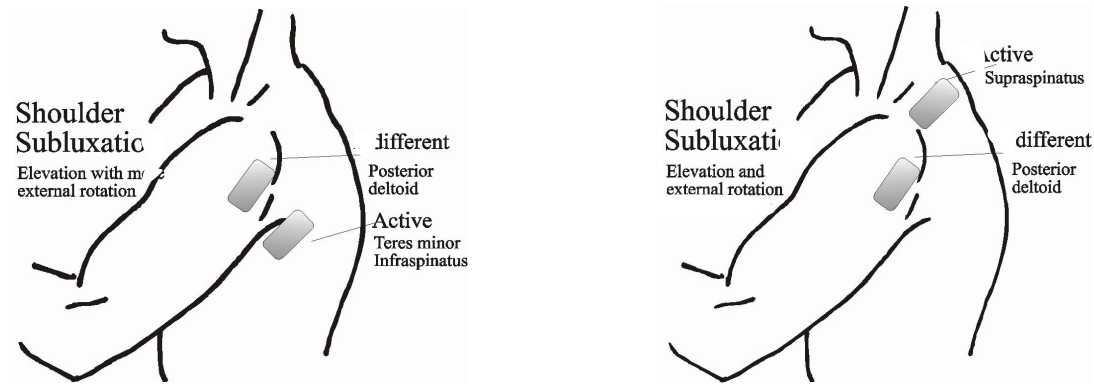


Fig.64. Application of electrodes in ESNM for shoulder subluxation

Scapular stabilization

Scapula alata¹ is a frequent complication of hemiplegia and is due to weakness of the trapezius and rhomboid muscles. These muscles can be trained by electrical stimulation (the position of the electrodes is shown in Fig. 65). The rhomboids retract and elevate the scapula, and the lesser trapezius, more superficial, adducts and lowers it.

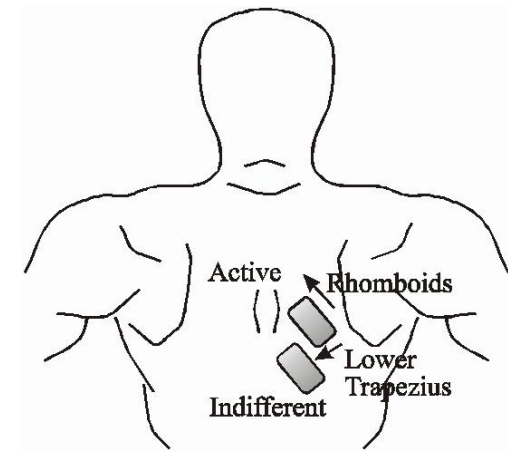


Fig.65. Application of ESNM for scapular stabilization

¹ It is a condition in which the shoulder blade protrudes into an abnormal position. It is a condition that leads to limitation of functional activity of the upper extremity. It can affect the person's ability to lift, push, pull heavy objects, in some cases even hindering daily activities such as combing hair. The name of this condition comes from the appearance of the medial edge of the scapula, which is detached from the back.

Elbow extension

The triceps is easily stimulated by placing the active electrode above the motor unit and the indifferent electrode above the tendon, at the elbow. As it is a fairly large muscle, large electrodes, for example 50mm x 50mm, will be used, which will produce a more efficient movement with greater comfort. Patients can be asked to assist the movement. An effective exercise would be to perform the “table polishing” exercise by sliding the hand on the table with a cloth in hand to reduce friction.

The action of the triceps can be supplemented by placing the indifferent electrode on the anterior deltoid, to assist shoulder flexion. The posterior deltoid can be stimulated to achieve shoulder extension, after the swing phase of the arm. If the biceps is also weak, stimulation of the triceps can be alternated with that of the biceps.

The active electrode is placed above the biceps muscle body, and the indifferent electrode two fingers below.

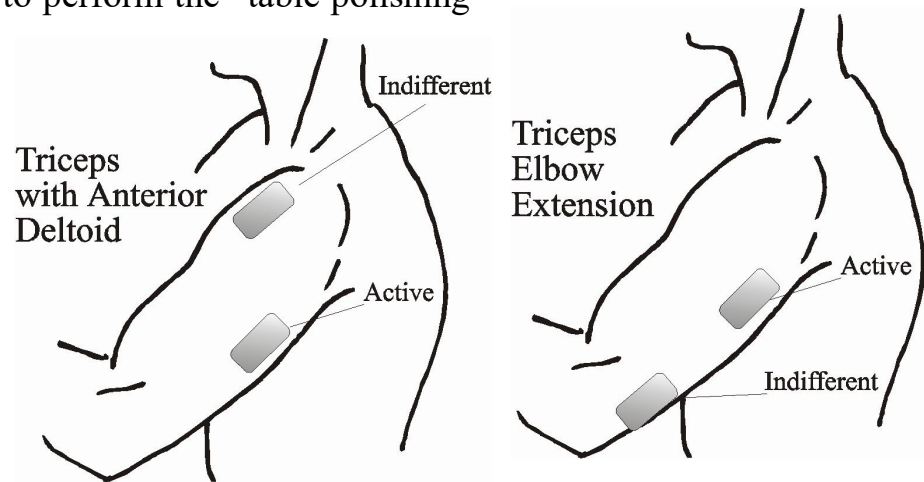


Fig.66. ESNM for elbow extension

Wrist, Finger II - V, and Thumb Extension

This is achieved by stimulating the radial nerve, which will determine a general pattern of extension. Thumb extension is often a problem, so place the indifferent electrode above the motor point of the distal phalanx of the thumb and the active electrode on the abductor pollicis, three fingers from the wrist joint. Avoid radial or ulnar deviation. If excessive ulnar deviation occurs, move the active electrode to the extensor carpi radialis brevis muscle, on the radial side of the arm.

If radial deviation occurs, move the active electrode to the ulnar side and to the extensor carpi ulnaris. If finger extension is poor, it may be due to spasticity of the flexor's fingers, when wrist extension is present, it will be necessary to stimulate only the finger extensors by placing the active electrode more distally. Since the common extensor of the fingers is deeper than the wrist extensors, it will be quite difficult to obtain pure finger extension.

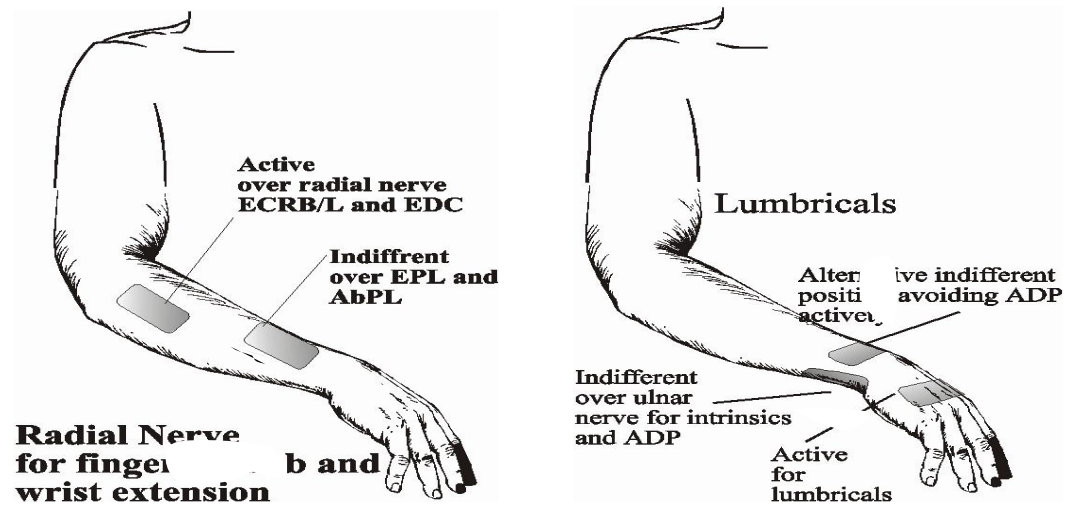


Fig.67. ESNM for extension of the fist, fingers II – V and thumb

Lumbrical and abductor pollicis stimulation

Radial nerve stimulation is often used to reduce the tone of spastic flexors of the fingers and thumb. The effectiveness of the stimulation can be improved by alternating radial nerve stimulation with lumbrical stimulation to produce flexion at the metacarpophalangeal joint with extension at the interphalangeal joints, thus producing a two-phase stretching of the finger extensors. This exercise can be effective in reducing hand edema. The two

muscle groups can be stimulated together to improve finger extension with extension of the fist and thumb. A thin and long active electrode (30x50mm) will be used, placed proximal to the bony extremities of the anterior wrist.

Since the lumbricals of the index and middle fingers are innervated by the median nerve, while the others are innervated by the ulnar nerve, the electrode will be placed above the index finger. The active electrode can be placed on the dorsal side of the wrist or above the ulnar nerve, at the entry into the wrist joint. Lateral placement will stimulate the adductor pollicis and other intrinsic muscles, which is often an advantage.

Thumb Abduction and Opposition

Radial nerve stimulation can be effective in opening the hand (fist), but isolated extension of the thumb may place it in a less functional position.

Abduction and opposition can be obtained by stimulating the thenar eminence. The active electrode will be placed on the motor point of the abductor pollicis brevis or on the opponens pollicis muscle and the indifferent electrode on the dorsal side of the wrist joint.

To combine this movement with a general extension pattern, a “Y” shaped connector will be used.

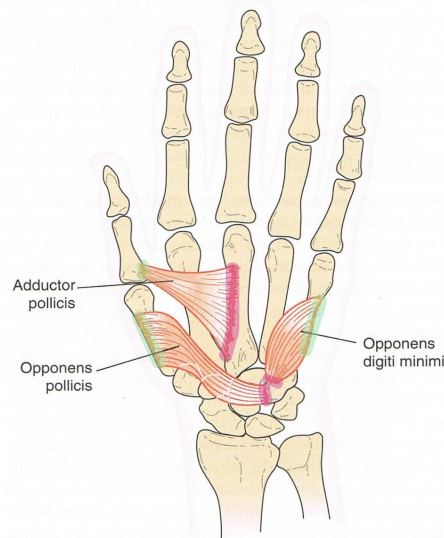


Fig.68. Opponens pollicis

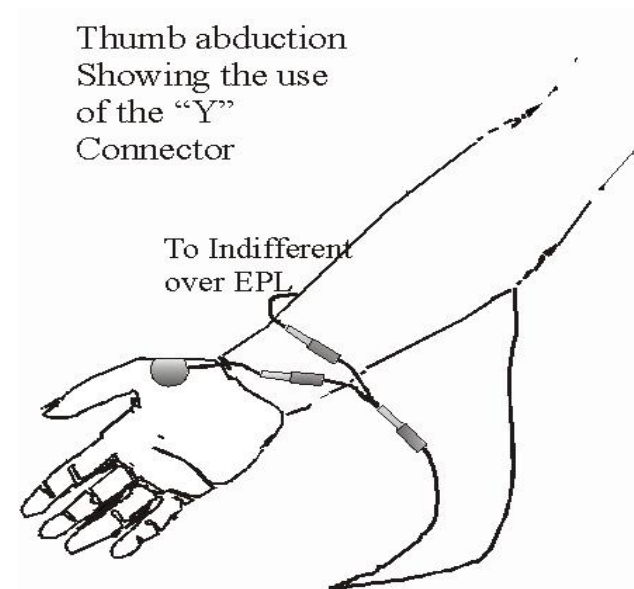


Fig.69.ESNM for abduction and big finger opponens

Figure 69 shows how the indifferent electrode lead can be split between two electrodes, one placed over the extensor pollicis longus (hidden behind the forearm) and the other over the abductor pollicis brevis, and the active electrode is placed over the radial nerve (also hidden). Strong abduction can be achieved by splitting the active electrode lead instead of the indifferent one.

Upper Limb Function Training

Recruiting muscles to achieve a gross movement pattern, similar to the combined movements of the upper limb, is often useful in training for activities of daily living. It is a method of regaining function that is more effective than selective muscle stimulation. An example of such a movement is reaching for an object, where the extension movement of the fist, fingers, and thumb is combined with elbow extension and shoulder flexion, by stimulating the triceps and anterior deltoid. If scapular stability is a problem, rhomboid and lower trapezius stimulation will be added.

Applications in tetraplegia

Electrical stimulation can be used to tone weakened, partially denervated, or paralyzed muscles, using the same electrode placements as described above. Stimulation of the median and ulnar nerves is useful, thus recruiting all the muscles of the forearm.

It should be noted that muscles can be denervated due to peripheral nerve damage, as a result of spinal cord injury. These muscles can no longer be stimulated. However, this type of stimulation can be used for diagnostic purposes to determine which muscles are denervated.

In this situation, the indifferent electrode is placed behind the elbow and the active electrode is placed on the target muscle, using a conductive gel.

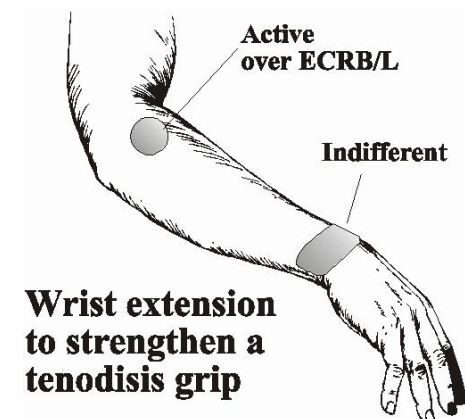


Fig. 70. ESNM application in tetraplegia

14.6.2. Electrostimulation for foot drop

Foot drop stimulation is a simple and effective method of using electrical impulses to improve the function of the lower limb, affected after a stroke, multiple sclerosis or other neurological conditions. Figure 71 shows the stimulation of the peroneal nerve through a device fixed at the hip, the self-adhesive electrodes being placed at the level of the calf, in its outer third, immediately below the knee.

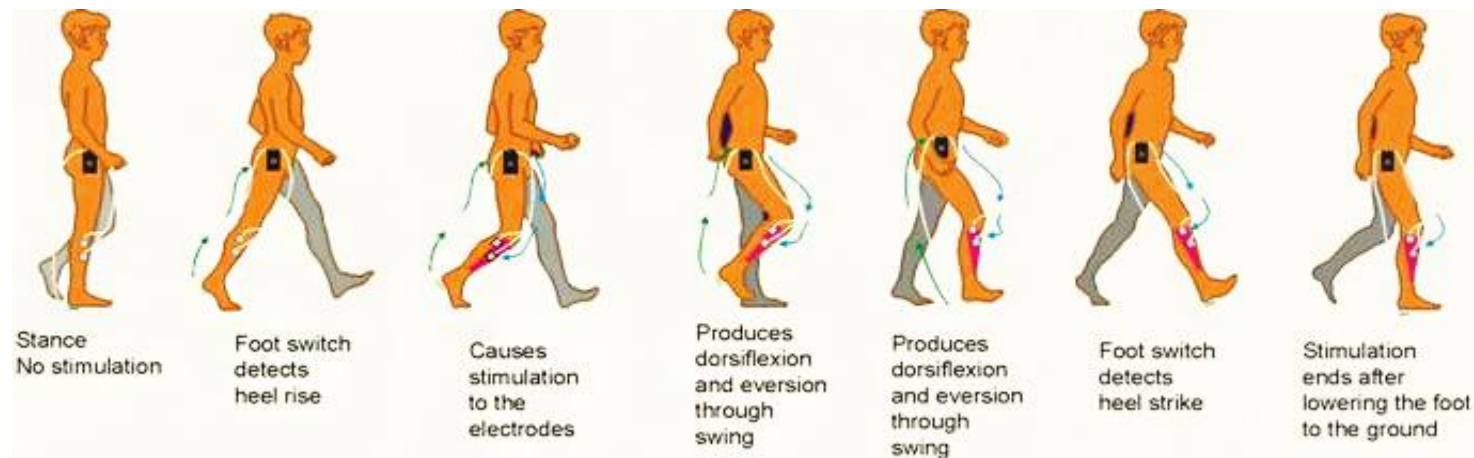


Fig.71. Neuromuscular stimulation for walking

One such stimulator is the Odstock Dropped Foot Stimulator (ODFS). This device allows stimulation timed to the patient's gait cycle using a pressure-sensitive switch (plantar switch) placed in the shoe, under the heel, and which is connected to the stimulator by a thin, non-restrictive wire. Stimulation begins when the heel is lifted off the ground and ends when the foot returns to the ground. Stimulation causes the foot to dorsiflex and thus assists in the excursion that the foot makes during the forward swing phase of the stepping movement.

Stimulation allows for stabilization of the ankle when weight is being placed on the affected limb.

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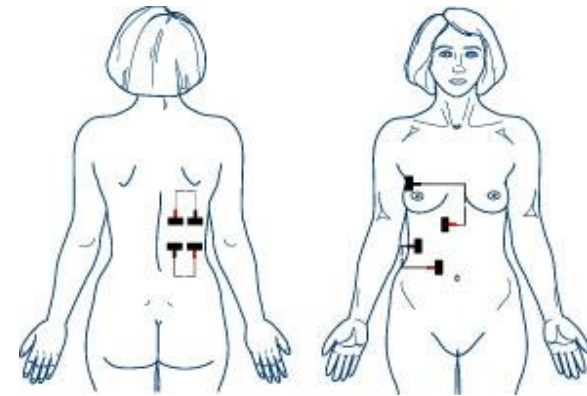
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Appendix 1. EXAMPLES OF TENS APPLICATIONS

1. Postherpetic neuralgia, for example, at right T6–T7

Program:

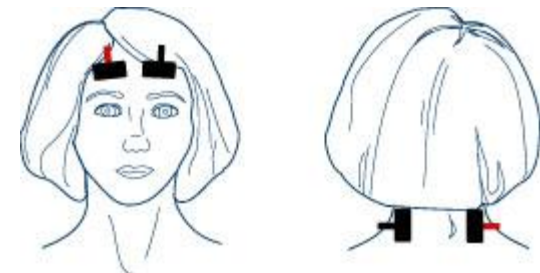
- high frequency: - the electrodes are placed in an area with normal sensitivity, within the dermatome, just above or below the affected segment. Or the electrodes can be placed on the same segment on the contralateral side
- low frequency: - the electrodes must be positioned so as to create a strong contraction of the intercostal muscles innervated by T6 – T7, which can be difficult.



high frequency

low frequency

2. Headache: In general, it does not matter where the red or black electrode is located. For high-frequency stimulation, a pulse duration of 60 μ s is recommended.



high frequency

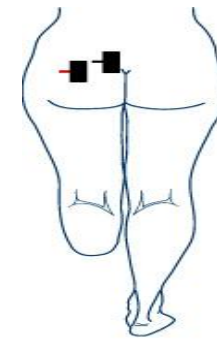
low frequency

3. Phantom limb pain

Program:

High frequency: Electrodes are placed paravertebral in the same segment as the pain. If there is normal sensation, the electrodes are placed on the contralateral side, such as at the level of the foot.

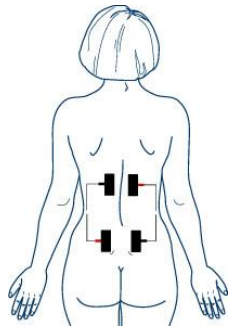
Low frequency: Electrodes are placed on the contralateral side in the same myotome as the pain.



high frequency



low frequency



4. Lumbago Program:

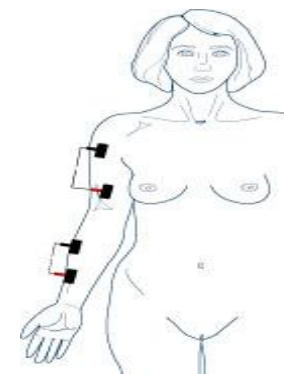
High Frequency: -In general, it does not matter where the red and black electrodes are placed. Large electrodes will be used. The electrodes are placed on the painful area.

5. Cervico-brachialgia area C6, right MS: pain in the right MS that radiates to the thumb.

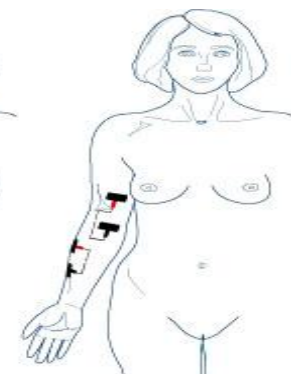
Program:

High frequency: If sensitivity is normal, the painful area (dermatome) will be stimulated.

Low frequency: The muscles in the myotome, such as the biceps or radial carpi extensors, are stimulated.



high frequency



low frequency



6. Lower back pain and sciatica:

Program:

High frequency in the lumbar area and

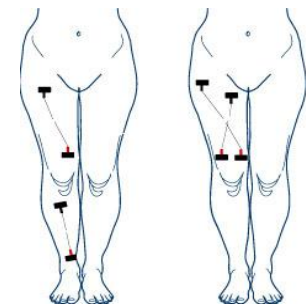
Low frequency on the posterior thigh, where sensitivity is reduced.

7. Sciatica: distribution from L4 on the right side.

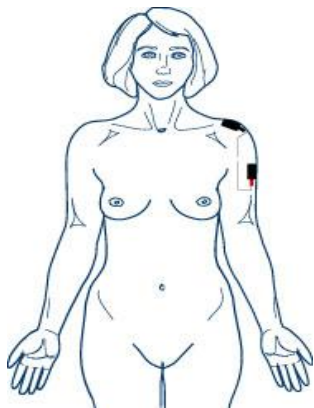
Program:

High frequency: at the level of the skin innervated by L4, if sensitivity is normal.

High frequency: above the muscles innervated by L4. A diagonal position allows for effective contractions.



Upper placement: low frequency.
Lower placement: high frequency.



8. Shoulder pain: radiates into the left shoulder, laterally and downwards, over the deltoid insertion.

Program:

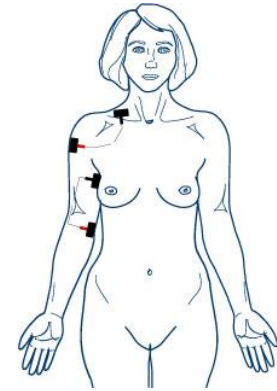
High frequency and possibly low frequency.

One electrode is placed over the joint space and the other over the deltoid insertion.

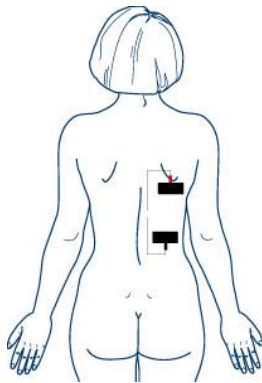
9. Central sensitization pain radiating to the right side

Program: high or low frequency

Paired electrodes are placed preferably over large nerve bundles, where the pain is more pronounced. In some cases, placement of the electrodes in the opposite area can be attempted. Central pain is often a difficult diagnosis to treat.



high frequency/low frequency



10. Post-fracture pain (ribs)

Program: High frequency

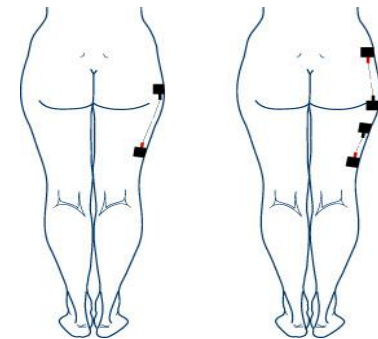
It is usually not necessary to determine the segmental innervation of the painful area of the body.

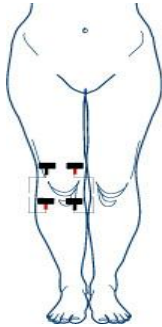
The electrodes are placed around the painful area. This usually successfully relieves pain after injuries such as rib fractures or spinal compressions.

11. Hip pain, right side

Program: high frequency

Place one electrode at the hip or proximal level and the other on the medial lateral edge of the thigh. In general, the location of the red and black electrodes does not matter.





12. Knee Pain

Program: High Frequency

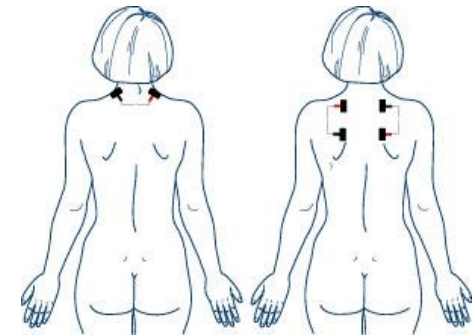
Electrodes are placed on each side of the joint space to facilitate flexion.

13. Muscle pain

Pain caused by muscle tension is most common in the neck and interscapular area. Trigger points or areas of hypersensitivity are usually found at this level.

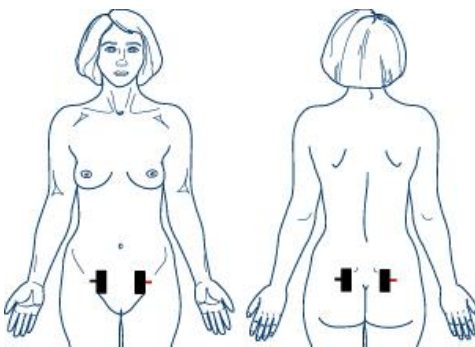
Program: high or low frequency

The electrodes are placed in the painful area, preferably above the points. For intrascapular irradiation, it is recommended to use two pairs of electrodes.



high frequency

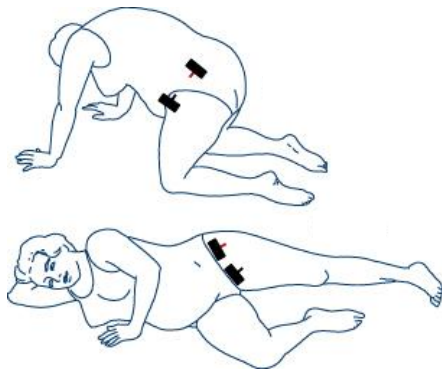
low frequency



14. Menstrual pain

Program: high frequency

The electrodes are placed in the painful area – lumbar or lower abdomen or both.



15. Symphysis pubis pain

Program: high frequency

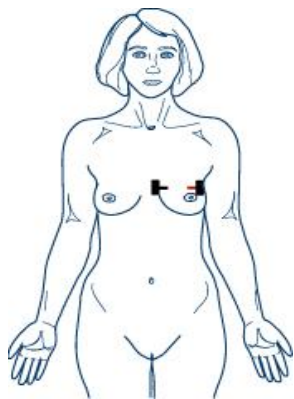
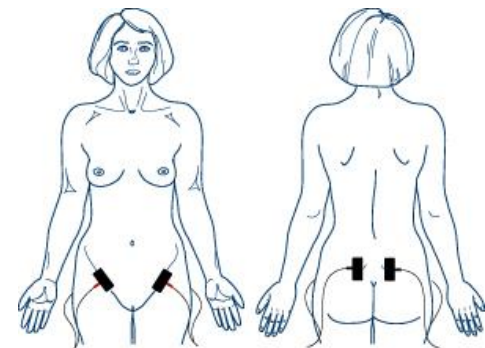
The electrodes are placed in the painful area (in the L1 segment, inguinal, or above the sacroiliac joint, at the sacral level). Avoid connecting paired electrodes above the symphysis.

16. Labor pain

Program: high frequency

Two to four electrodes are placed in the painful area, usually in the sacral region. Large electrodes are more effective in this situation. Later in labor, the pain migrates anteriorly and downwards. Two electrodes are placed in the lumbar region and two more in the hips/groin area.

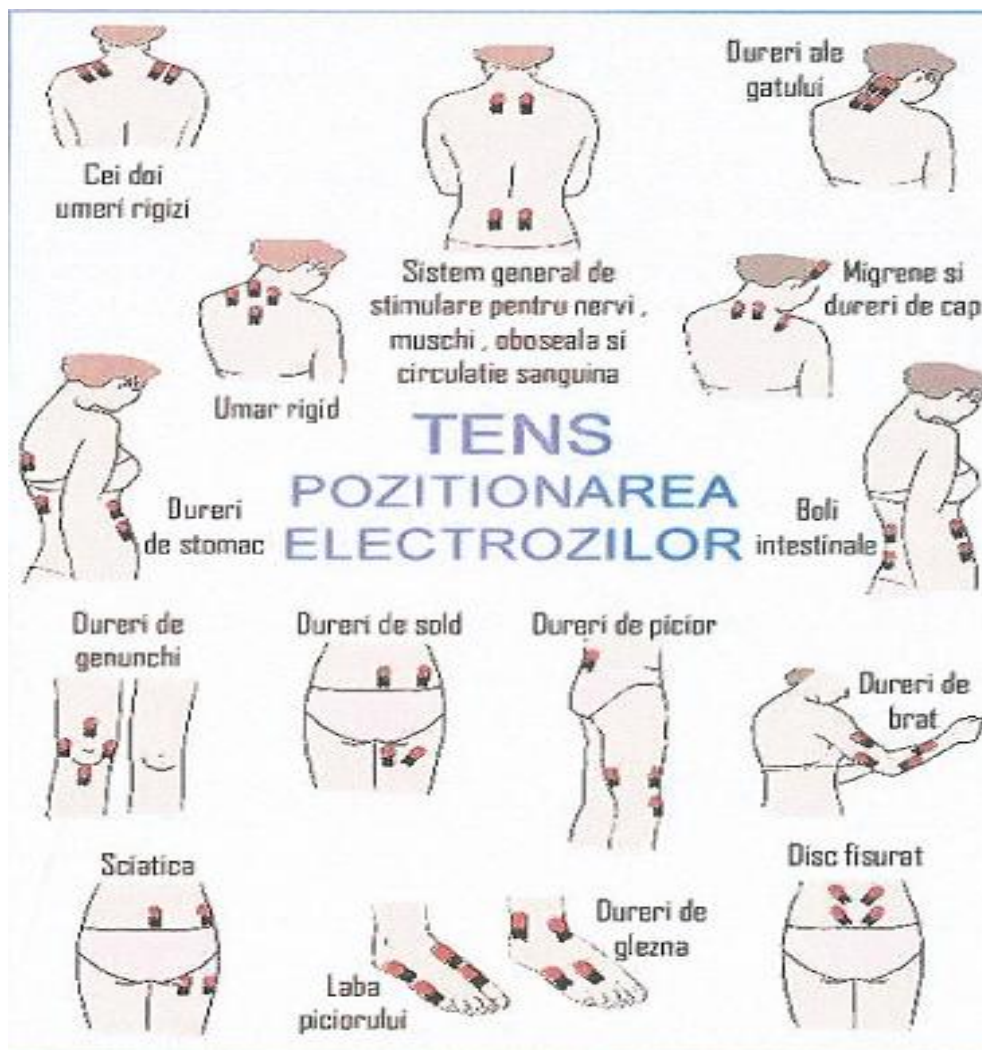
Note: Avoid connecting pairs of electrodes over the uterus.



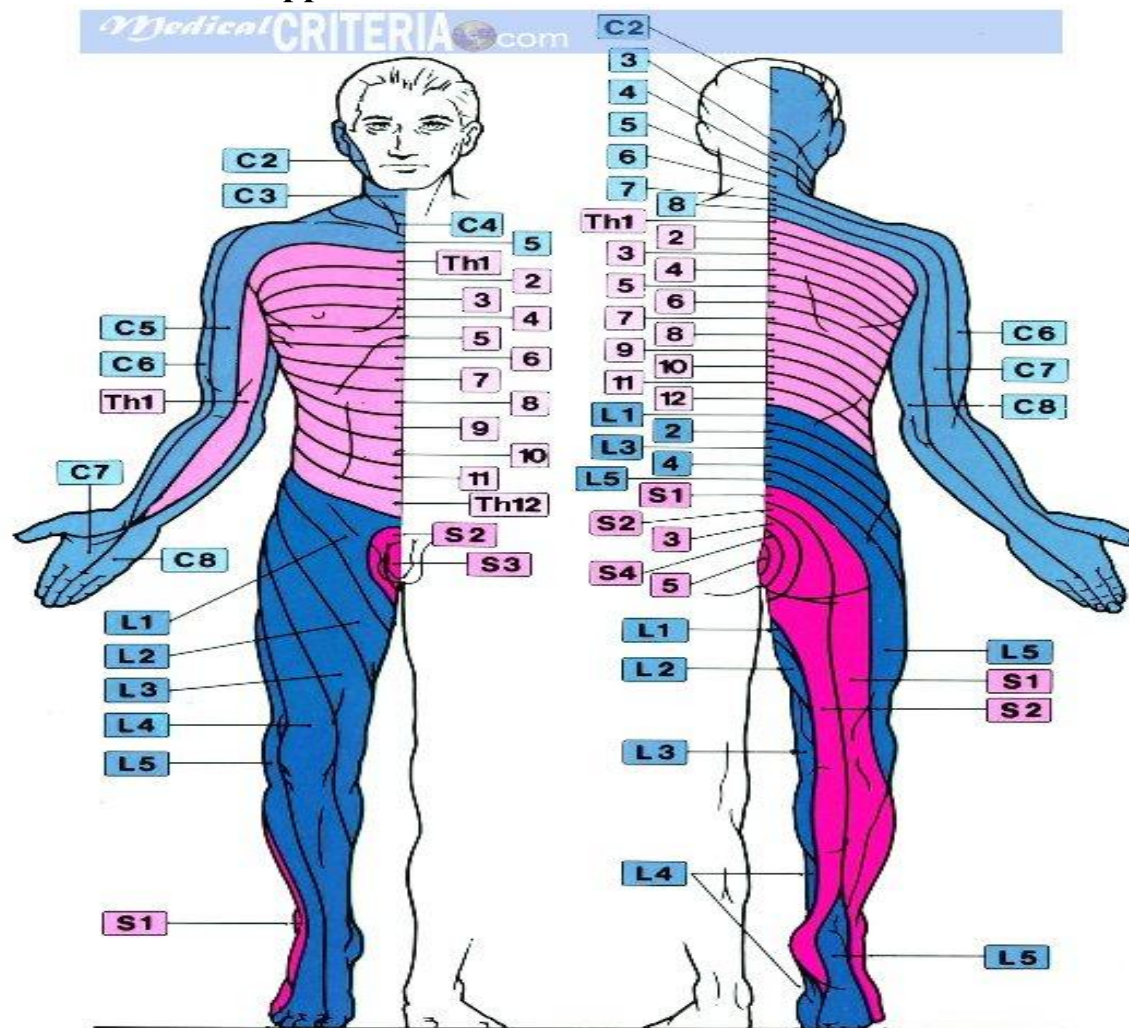
17. Angina Pectoris

The electrodes are placed on the painful area. In general, the placement of the red and black electrodes does not matter. For acute ischemic pain, high-frequency stimulation with very high amplitude can be used for a very short period of time (60 seconds). This procedure is called high-intensity stimulation. This procedure is performed in cardiology clinics.

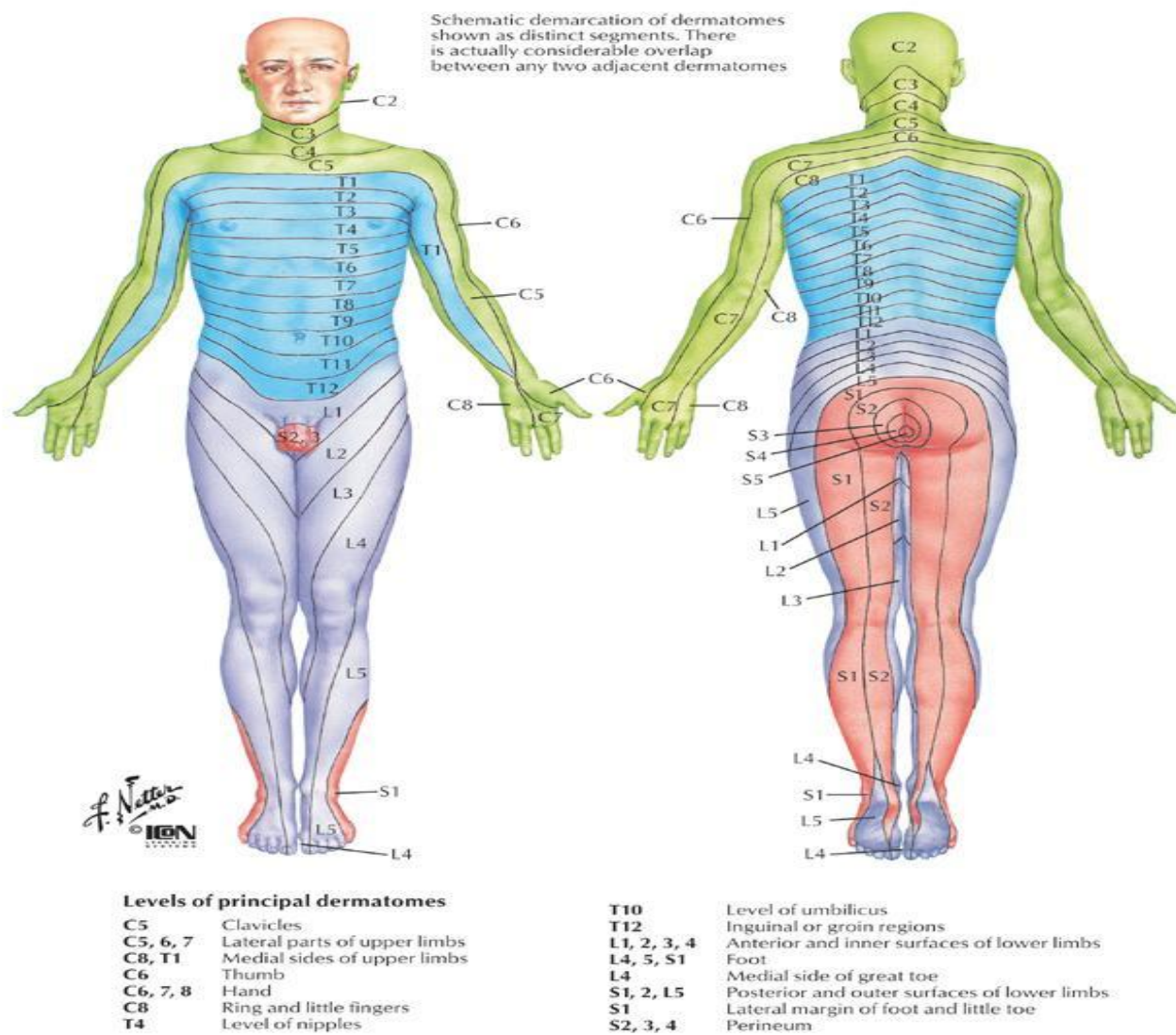
Appendix 2. TENS APPLICATIONS



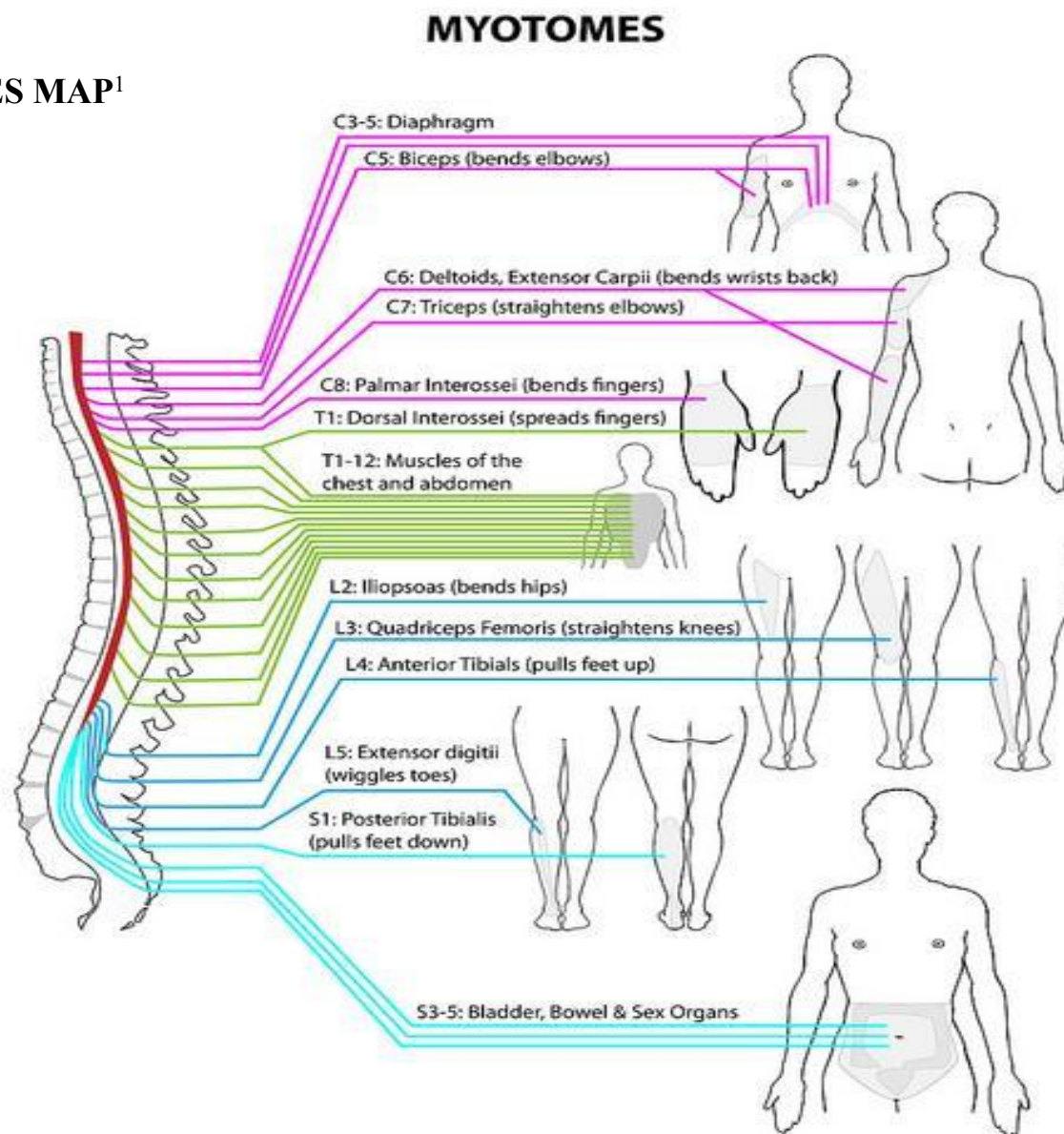
Appendix 3. DERMATOMES MAP¹



¹ <http://www.studyblue.com/notes/n/dermamytome/deck/5473789>



Appendix 4. MYOTOMES MAP¹



¹ <http://www.studyblue.com/notes/n/dermamylotome/deck/5473789>

CERVICAL AND LUMBAR-SACRAL MYOTOMES ¹

CERVICAL MYOTOMES					
• ANT. PRIMARY RAMI	C5	C6	C7	C8	T1
SHOULDER GIRDLE GROUP •					
RHOMBOID MINOR					
RHOMBOID MAJOR					
SUPRASPINATUS					
INFRASPINATUS					
DELTOID					
BICEPS BRACHII					
SERRATUS ANT.					
RADIAL NERVE GROUP •					
BRACHIORADIALIS					
ANCONEUS					
TRICEPS					
EXT. CARPI RADIALIS					
EXT. DIG. COMMUNIS					
EXT. CARPI ULNARIS					
EXT. POL. BREVIS					
EXT. POL. LONGUS					
EXT. INDICIS PROP.					
MEDIAN NERVE GROUP •					
PRONATOR TERES					
FLEX. CARPI RADIALIS					
FLEX. DIG. SUBLIMIS					
FLEX. POL. LONGUS					
PRONATOR QUADRATUS					
ABD. POL. BREVIS					
ULNAR NERVE GROUP •					
FLEX. CARPI ULNARIS					
FLEX. DIG. PROFUND. (MEDIAL)					
ABD. DIG. MINIMI					
ADD. POLICIS					
FIRST DORSAL INTEROS.					
• POST. PRIMARY RAMI					
C5 - T1 PARASPINALS					

REPRESENTATION  MAJOR  MINOR  EQUIVOCAL

LUMBAR - SACRAL MYOTOMES						
• ANT. PRIMARY RAMI	L2	L3	L4	L5	S1	S2
FEMORAL / OBTURATOR GROUP •						
ILIACUS						
THIGH ADDUCTORS						
QUADRICEPS FEMORIS						
GLUTEAL / SCIATIC GROUP •						
GLUTEAL MED.						
GLUTEAL MAX.						
INT HAMSTRINGS						
EXT HAMSTRINGS						
PERONEAL GROUP •						
TIBIALIS ANT.						
EXT HAL LONG.						
EXT DIG BREV.						
PERONEI						
TIBIAL GROUP •						
TIBIALIS POST.						
FLEX DIG LONG.						
GASTROC LAT.						
GASTROC MED.						
SOLEUS						
ABD. DIG. Q. PEDIS						
ABD. HALLUCIS						
• POST PRIMARY RAMI						
L2 - S2 PARASPINALS						

REPRESENTATION:  MAJOR  MINOR  EQUIVOCAL

¹ <http://thephysiotherapy.com/lower-limb-myotomes/>

Appendix 5. ELECTRODE PLACEMENT FOR MUSCLE ELECTROSTIMULATION

The electrode placement diagram is only a recommendation, a guide. There is no exact science of electrode placement, the result of stimulation varies depending on the individual (sensitivity to electrical stimuli varies from one person to another). ESM is a means of training, toning and recovery that must be adapted to the patient. The ideal intensity is reached when a muscular contraction is strongly perceived by the patient, without being painful or unpleasant. It is advisable to experiment with different electrode placements to obtain the optimal contraction.¹



Chart #1



Chart #2



Chart #3



Chart #4



Chart #5



Chart #6



Chart #7



Chart #8

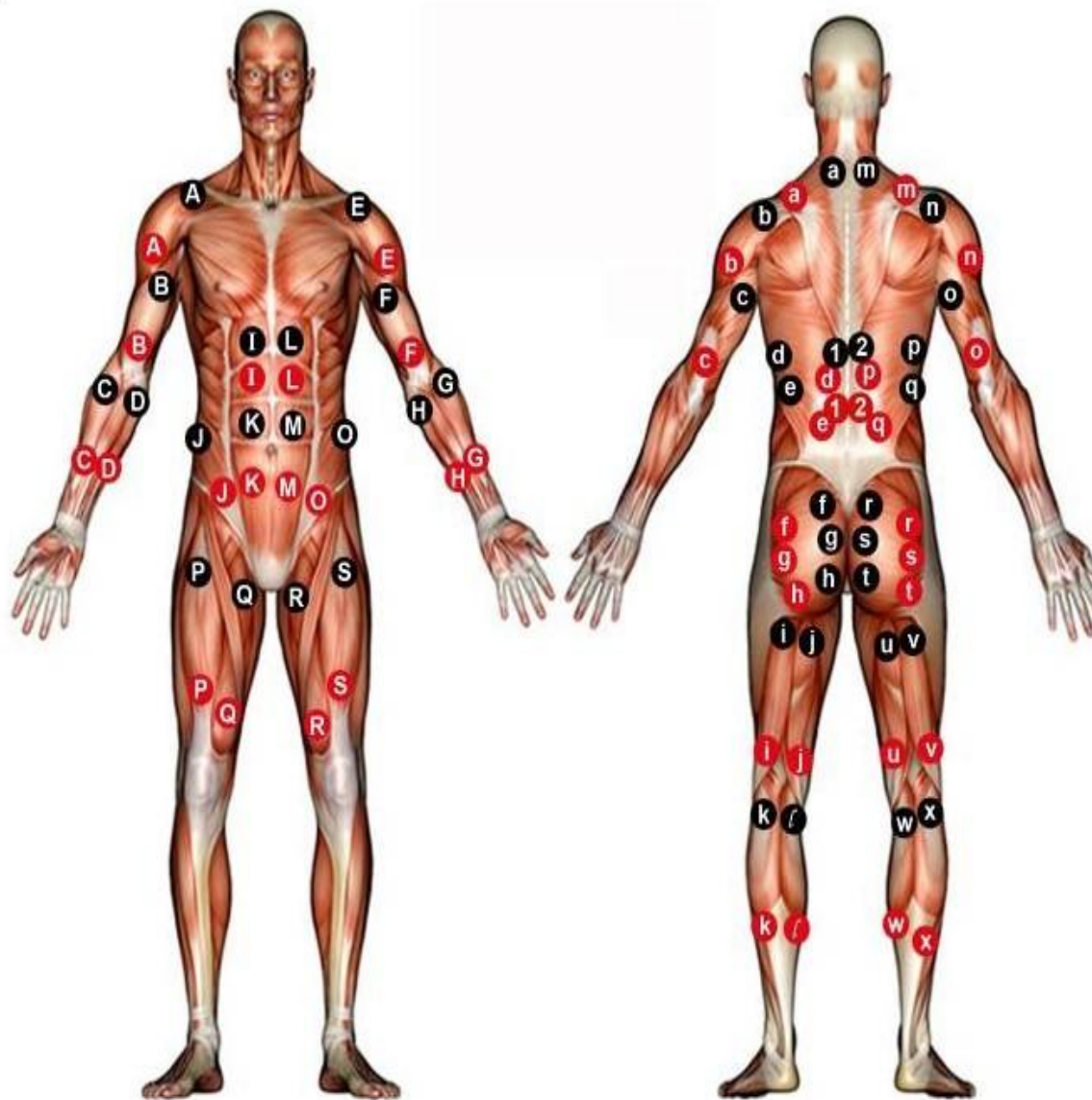


Chart #9



Chart #10

¹ <http://www.militarystim.com/pad-placement.html>



Red Electrode (Positive)
Black Electrode (Negative)

A-A, E-E, b-b, n-n: Deltoid
B-B, F-F: Biceps
C-C, G-G: Brachioradialis
D-D, H-H: Radialis Muscles
I-I, K-K, L-L, M-M: Rectus Abdominis
J-J, O-O: External Oblique
P-P, S-S: Quadriceps Femoris
Q-Q, R-R: Adductor Muscles
a-a, m-m: Trapezius
c-c, o-o: Triceps Brachii
d-d, e-e, p-p, q-q: Latissimus Dorsi
f-f, g-g, h-h, r-r, s-s, t-t: Gluteus Maximus
i-i, v-v: Thigh Biceps
j-j, u-u: Semitendinosus
k-k, l-l, w-w, x-x: Gastrocnemius
1-1, 2-2: Erector Spinae