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Acupuncture & electrotherapy: An alternative and complementary treatment method

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Abstract

Acupuncture involves activating specific points on the skin, usually by inserting needles. Acupuncture was based on the principles of traditional Chinese Medicine. Traditional acupuncturists understood health in terms of a vital force or energy called "Qi" that circulates between the organs along channels called meridians. The flow of 'Qi' energy must be of the right strength and quality in each of these meridians and organs so that health is maintained. Acupoints are located along the meridians and can alter the flow of energy and appear to correspond to nerve endings. There is a distinct difference between traditional and Western acupuncture, but the two approaches overlap significantly. In terms of Western theories, acupuncture induces signals in central nerves that modify the transmission through the spinal cord, as well as the perception of pain in the brain. Electrotherapy leads to stimulation of the sensory and motor nerves, and is especially used in the treatment of pain. Different set of parameters may lead to different physiological effects and treatment may be more specific. Electroacupuncture can be performed with or without needles, activating traditional acupuncture points or choosing points that have a neural background, such as trigger points or tender points. The purpose of this study is to verify that acupuncture works as an effective alternative and complementary treatment method. It is a safe, effective and natural approach, which helps to regain and maintain health and mental well-being.

Keywords: Acupuncture; Electrotherapy; Electroacupuncture; Pain; Endorphins

1. Introduction

In 1987 Pomeranz proposed the theory that acupuncture stimulation activates A-d and C fibers in the muscles, which leads to the transmission of signals to the spinal cord, which in turn leads to the local release of dynorphin and enkephalins. These local processes are transmitted via centromere pathways to the midbrain, where they activate a series of excitatory and inhibitory transmitters in the spinal cord. The eventual release of neurotransmitters such as serotonin, dopamine, and norepinephrine in the spinal cord results in pre- and postsynaptic inhibition and inhibition of pain transmission. When these signals reach the hypothalamus and pituitary gland, they trigger the release of cortico-adrenostimulating hormone and endorphins. Pomeranz's theory was confirmed by numerous experiments in his research laboratory, as well as by other researchers. This fundamental principle of acupuncture-induced analgesia has been explored over the past three decades and with a number of neurophysiological and imaging studies. Energy roads (King) are called meridians. Meridians are the imaginary lines on the body, joining specific acupuncture points. There are 12 meridians within which energy circulates at a certain rate non-stop. During two hours at each meridian there is a state of maximum energy supply. The 12 meridians are arranged in pairs, which means they are exactly symmetrical left and right, in relation to the midline of the body. Each meridian is responsible for an organ or a group of functions. These 12 meridians are then divided into 6 Yang and 6 Yin meridians, not meaning that each category has only Yang or possibly only Yin energy circulating. This name has to do with the operation of the particular organ for which they are responsible. Thus it is possible to distinguish between Yang and Yin conditions. In other words, these are diseases that have Yang hyperfunction or Yin deficiency or over (Yang) or under (Yin) function. These roads, the basic lines where the energy circulates, it must be emphasized that they have nothing to do with blood circulation (1).

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It has been shown that the transmission of information between two neurons is electrochemical and can be affected by acupuncture due to the metal construction of the needles. Chemical transmission of the stimulus simultaneously controls and influences the transmission of different information in the same neuron. In the central nervous system, chemical transmitters such as norepinephrine, dopamine and acetylcholine act stimulatory, while others such as serotonin act inhibitory. Impulses on axon terminals are concentrated from different regions and can release excitatory or inhibitory neurotransmitters, which have respective agonistic or antagonistic effects on the same postsynaptic neuron. Acupuncture can affect neurons, facilitating the transmission of the stimulus through the synapses (2).

In 1997 the US National Institutes of Health accepted the fact that there is sufficient evidence for acupuncture to expand its use in conventional medicine. Acupuncture has been used as a health care modality for over 3000 years. Practitioners of the medical practice of acupuncture have shown clinical success in a variety of health problems. Today acupuncture enjoys wide clinical acceptance. Most people have associated acupuncture with pain control. However, acupuncture has a proven track record in treating endocrine, circulatory and systemic diseases. Acupuncture and modern medicine have the potential to support and empower patients' health and well-being. What is known about the effects of acupuncture? In recent decades, research has attempted to explain how acupuncture works and what it is indicated for (3).

2. Results

In 1997 the National Institutes of Health (NIH) states that: "studies have shown that acupuncture can elicit biological responses mediated primarily by sensory neurons in many structures of the central nervous system. This can lead to activation of pathways that act on a variety of physiological systems in the brain, as well as in the periphery." The NIH also suggests that acupuncture may activate the hypothalamus and pituitary gland and lead to a wide range of systemic effects. Changes in neurotransmitter and hormone secretion and changes in blood flow regulation have been documented. There is also sufficient evidence for the observed changes in immune system function induced by acupuncture. The following are the current theories regarding the mechanism of action of acupuncture: The Neurotransmitter Theory: acupuncture acts on higher areas of the brain, activating the secretion of b-endorphins and enkephalins in the brain and spinal cord. The release of neurotransmitters affects the immune system and "anti-algesic" mechanisms to stop pain. The Autonomic Nervous System Theory: acupuncture stimulates the release of norepinephrine, acetylcholine as well as various types of opioids, leading to a balancing of the autonomic nervous system and a reduction in pain. The Gate Control Theory of pain: acupuncture activates "anti-algesic receptors", which prevent the transmission of analgesic signals to the dorsal horn and thus exclude noxious stimuli. Vascular-Interstitial Theory: acupuncture manages the body's electrical energy by creating a closed transport circuit in the tissues. This process facilitates healing by allowing the transfer of electrical energy between normal and injured tissue. The Blood Chemistry Theory: Acupuncture affects blood concentrations of triglycerides, cholesterol, and phospholipids, leading to the conclusion that acupuncture may increase or decrease peripheral blood components so that to regulate the body's homeostasis (4).

According to a study published in the Archives of Internal Medicine, 51% of physicians perceive the effectiveness of acupuncture, and most clinicians refer their patients to acupuncturists, more than any other alternative care provider (Astin1998). The NIH notes that clinical experience based on research data supports the use of acupuncture in a number of clinical conditions. There have also been positive clinical trials for addiction, stroke recovery, carpal tunnel syndrome, osteoarthritis and headache. It is also reported that acupuncture treatment can be useful in other conditions such as asthma, post-operative pain, back pain. Indeed, acupuncture has been used to treat many painful conditions, such as low back pain, chronic shoulder and neck pain, osteoarthritis of the knee, migraine, dysmenorrhea, and acute postoperative pain. Sun et al (2008) conducted a systematic review to assess the effectiveness of acupuncture and related techniques in the management of postoperative pain. They concluded that preoperative acupuncture can be a useful, additional tool in the treatment of postoperative pain. It is noted that under the "umbrella" of acupuncture, a number of different techniques are often placed and that the relevant studies are not always methodologically sound. As a consequence, although the results are encouraging, their generalization should be done with caution (5, 6).

Regarding the physiological mechanisms at the biochemical and genetic level, it has been found that acupuncture (traditional and electroacupuncture) activates the hypothalamus and nuclei of the brain, as well as the primary sensory cortex, while it deactivates part of the cortex of the afferent helix. At the gene level this translates into activation of endorphin production genes. One of the advantages of acupuncture is that the potential for side effects is significantly lower than that of many drugs and medical methods used for the same conditions. For example, musculoskeletal conditions such as fibromyalgia, epicondylitis, tennis elbow and fasciitis syndrome are conditions in which acupuncture can be helpful. These painful conditions are often treated with anti-inflammatory drugs (aspirin, ibuprofen) or steroid injections. Both medical methods have the potential for adverse side effects, but are widely used as acceptable treatments. The evidence supporting these treatments is no better than that for acupuncture. In summary, acupuncture

therapy has a direct relationship with the somatosensory nerves and the Autonomic Nervous System. Placing a needle in a strictly selected point and in a specific area inhibits the transmission of impulses to the somatosensory nerves. Acupuncture works by causing the pain gate to close, thereby blocking the transmission of impulses to the central nervous system. At the same time, it leads to the secretion of endogenous opioids (endorphins), which also explains the analgesic effect of acupuncture in surgery. Acupuncture works as an effective alternative and complementary treatment method. It is a safe, effective and natural approach, which helps to regain and maintain health and mental well-being (7,8).

"The phenomenon of electricity and the laws governing it are an admirable achievement, as they become evident in inorganic matter, but there can be no comparison at all when their application is extended to the nervous system and by extension to life itself" (Michael Faraday). Electroacupuncture has its roots in Western electrotherapy as well as Eastern traditions. After two and a half centuries, much remains unknown about how both direct current and low-frequency current affect us. In general, they have three actions: chemical (as in electrolysis), physical or stimulating and thermal action. These actions can affect the body at various levels such as: at the cellular, at the tissue, at the segmental and at the systemic level. At the cellular level, we may have effects on cellular chemistry (such as enzyme or protein synthesis), on fibroblasts, osteoblasts or mitochondria, changes in the permeability of cell membranes, as well as in the stimulation of peripheral nerves and muscle fibers and finally changes in microcirculation (arterial, venous or lymphatic). Actions on tissues include muscle contraction, tissue regeneration and remodeling, and changes in overall thermal and chemical balance. Segmental contraction of muscle groups can in turn produce a pump action in the larger arteries, veins and lymphatics. Direct current stimulation was the first form of electrotherapy, after a brief initial phase where static electrical discharges were used. Because of its electrolytic action, it is now of little use in nerve and muscle stimulation (although high-voltage monophasic stimulation with very short pulse duration may potentially have some use) (9).

Electrotherapy leads to stimulation of the sensory and motor nerves and is particularly used in the treatment of pain. Electroacupuncture mainly uses transdermal stimulation. Both transcutaneous electrical nerve stimulation (TENS) and electroacupuncture owe their action mainly to sensory stimulation, using low-frequency biphasic currents with low power (less than 5 W) and relatively short pulse duration (generally between 0.01 and 0.4 ms). With these parameters, any heat generated during the transfer of electrical energy to the tissues is easily dissipated and the oxidative and electrolytic action is minimal. There is of course a small chance that the ionic products released in one pulse are not necessarily recovered in the electrochemical reaction produced by the reverse pulse. This is impossible to happen if the interval between pulses is short. The electrical stimulation of a nerve above the threshold (minimum limit) of depolarization leads to the production of an energy potential, similar to that produced physiologically, only that its course along the nerves includes both directions, orthodromically (in the direction of conduction of the nerve) and in the opposite direction. The threshold for each fiber depends on the applied pulse, i.e. on its amplitude and duration. Once the stimulation threshold leads to the generation of the action potential then the application of stronger stimulation does not change the action potential, but activates more fibers. In a short-duration pulse, the current must be strong to result in an energy potential. The longer the pulse duration, the less current is required (pulse duration longer than about 5 ms for motor and sensory fibers). The initiation of stimulation of the algesetic fibers takes place in a pulse duration of the order of 1 ms, both in healthy individuals and in patients with chronic pain. Therefore there is no advantage to using a longer pulse duration. By using trains of pulses, the amount of current per pulse required to activate the energy potential is less compared to that required for a single pulse. Thus pulse trains can be an effective and pleasant form of stimulation. Motor (Aa) nerves are deeper than cutaneous sensory (Ab) nerves, so require more stimulation to be activated transdermally (even though they are thicker and thus have a lower threshold and less electrical resistance to external stimulus). Noxious (A and C) skin fibers, which are thinner, need more stimulation to fire. The threshold differs in different parts of the body, so for example it is higher in transdermal stimulation for the lower extremities than for the forearm. There is a range of response for the different types of fibers, so the minimum pulse duration leading to the generation of action potentials for Ab, Ac and C fibers is 0.20 ms, 0.45 ms and 1.50 ms respectively. A pulse duration of 200 μs is impossible to cause pain. More current can reach closer thin fibers than thicker more distant ones. To avoid inadvertent stimulation of C fibers, it is important that the electrodes are placed as close as possible to the target tissue. In addition to pulse width and duration, rise time and pulse shape are equally important. Emil DuBois–Reymond observed that adaptation to a stimulus exists only when the change is gradual. If a pulse increases gradually, the firing threshold increases automatically. Because of the larger capacitance of the contact electrodes, this effect is particularly pronounced with transdermal stimulation, rather than with needle stimulation. To trigger fast depolarization in a nerve fiber, a rise time of less than 60 μs is required, with rectangular or spike-shaped waveforms, but not triangular. Thicker nerve fibers have a shorter inexcitable period, as well as a lower threshold, so an energy potential is generated in response to each pulse, with current characteristics such as high frequency, low intensity, and short pulse duration. Minimal current is required at frequencies of 60-100 Hz for medium and large myelinated fibers. In the finer fibers with the longest non-excitation period, low frequency stimulation with high

intensity and longer pulse duration is required. Electrical stimulation at the motor level activates motor and sensory neurons, leads to muscle contraction, detectable by palpation and then visible by the movement of muscle groups. However, the response to external stimulation is diametrically opposed to the normal one and is characterized by rapid, easy fatigue of the motor units and their thicker neurons firing rapidly. The electrical capacitance of muscle fibers is ten times greater than that of nerve fibers, and for this reason it takes longer to reach the firing pathway (about 35 ms). The result is that for muscles that are normally innervated, the electrical stimulation is always via the motor neuron. In denervated muscles, where the distribution of the nerve has been interrupted, the muscle fiber itself is activated. As for the effect on the muscles of continuous pulses and bursts of pulses (pulses interrupted by a few milliseconds), in the latter case the intermittent current enables the muscles to relax between contractions and thus less fatigue occurs of the muscles. Ratio (start/stop) of the order of 1:3 and 1:5 lead to less fatigue than a ratio of 1:1 or 1:2. Stimulation at the motor level can lead to muscle strengthening, facilitation of muscle control, reduction of spasticity, beneficial effect on microcirculation and faster tissue healing. Muscle mobilization, whether natural or artificial, exerts a pump action on blood and lymph circulation, enhancing oxygenation and removing lactic acid and other metabolic products. The skin is like an electrolyte conduit rich in extracellular and intracellular ions. The existence of ions on the outer cell surface (surface potential) causes the appearance of an electromagnetic field. Factors affecting the passive electrical activities of the skin are: skin perfusion, skin thickness, hair growth in the area, electrode difference on the skin, sweat, psyche, intense visual and auditory phenomena and the contact surface of the electrodes. The tissue electrical resistance to the current passage depends on several factors. Body fluids have electrolytic properties.The path that the electric current moves within the body after leaving the needles is related to the ion current, which follows the points of the body with the least electrical resistance. Internally the body is a good conductor of electricity. By applying two electrodes into the skin with an electrical voltage, the current tends to flow into the extracellular space because cell membranes have a high resistance. The ions respectively reach the electrodes and depending on their degree of ionization, donate or take electrons. The cell membrane constitutes a biological protective barrier to currents from external sources. The high electrical resistance (low conductivity) of the outer layer of the skin is an electrical barrier protecting the body from external electrical reactions. High-intensity electric currents, if they can cross the cell membrane, cause permanent or non-permanent damage. The low intensity electric currents that penetrate the distance between the two electrodes, cross the road with the least electrical resistance. The passage of small electrical currents in the skin does not correspond to known anatomical pathways. It is, however, the same as about 75% of the superficial course of the Chinese meridians (10).

Acupuncture points have lower electrical resistances than their surroundings and therefore current passes much easier through these points. Meridians are channels of energy because the current produced by the natural electrical activity of the cells, as it travels within the tissues, follows the specific course of least electrical resistance. The application of two electrodes at different points on the skin causes an electric current between them, which is formed by the ions arranged in the extracellular fluid and a part of it crosses the cells, which are stimulated. The response is modulated by the type of cell stimulated, visual image (iris cells), muscle contraction (muscle cell), auditory signal (auditory cells). Human tissue is a good conductor of electricity. Conductivity is different from person to person, but even within the same person there are differences between areas of the body. Acupuncture points are not only found in the skin, but also in the underlying tissues. The resistance of the current is affected by the distance between the acupuncture points, as well as by the fat content of the skin. The movement of electric charge (Q) in a certain direction is called electric current. If the electric current has the same direction it is called direct, while if it constantly changes direction then it is called alternating. The surface of the skin carries positive surface charges and the glands carry negative charges. The basal layer of the skin carries positive charges.From the constant exchange of ions between the outer and inner layers of the skin, a change in the polarity of the skin layers is created, with the possible eventual manifestation of some pathology. The electrical activity of the skin is controlled by the postganglionic fibers of the sympathetic system, the subcutaneous glands, the vascular perfusion and the myoepithelial fibers of the glands. By stimulating the points of acupuncture with electric current, we increase the results of acupuncture. With the help of electroacupuncture we have intense local tissue stimulation, resulting in the improvement of local blood and lymph circulation, an increase in tissue metabolism, faster tissue healing and special effect on muscle and nerve level (11).

The electric generator of the electroacupuncture machine creates the appropriate voltage (V), which it sends out in a specific form of pulses. Then, with the help of two electrodes, the electric current is channeled onto the corresponding needles, which have previously been placed at specific acupuncture points. The superficial and deep tissues of the region exhibit a resistance (R) to the passage of current. According to the well-known Ohm's law (I= V/R), which states the relationship between intensity (I), voltage (V) and resistance (R) of the electric current, when the intensity increases then the voltage also increases, as these two parameters are directly proportional. Thus, correspondingly, the current delivered to the patient will be more intense, when the intensity of the electric current increases. The resistance (R) depends on the distance between the electrodes. When the distance increases, then the resistance increases, resulting in a decrease in intensity. Electro-acupuncture machines are usually low voltage (0.5-1.5 V) and can cause appropriate

electrical stimulation to muscles and nerves. This is particularly helped by placing the needles in strategic points of muscle and nerve stimulation, very close to the corresponding area of action, so that only a low-voltage current is necessary (12).

In direct contact with the muscle, muscle contraction is observed at a voltage of 1-3 V, while in direct contact with the nerve, muscle contraction is observed at a voltage of 0.4-1.5 Volts. The patient generally feels the current at a voltage of 0.3-1.2V. By gradually increasing the current, visible muscle contractions appear, as the threshold potential for muscle contraction ranges from 0.4-2.5V. We should be especially careful when adjusting the machine, because a continuous increase in voltage causes pain. It should be noted here that the threshold potential for the sensation of pain is 7-14 Volts, as long as the other parameters of the current are constant. The electrical current in electroacupuncture is usually alternating current with an asymmetric waveform. Usually the direction of electron flow reverses steadily and periodically. The magnitude of the current flow is constantly changing, but the duration of the flow can be changed. There are many forms of pulses from electroacupuncture machines. The sharp or square pulse usually predominates. With the use of the sharp pulse, stimulation occurs, while with the application of the square pulse, decay occurs (13).

The intensity of the current administered during electroacupuncture is at particularly low levels. When electroacupuncture is applied to the acupuncture point at a depth of 1 cm with a sharp waveform with a frequency of 20 Hz, then at 50-80 μA the sensation of current begins, at 500-650 μA the patient feels pain, and at 900 μA he cannot tolerate the current of electroacupuncture. So the ideal intensity when applying electroacupuncture is 100-500 mA which is comfortably tolerated by the patient. After a few minutes of applying the current, the electroacupuncture sensation usually diminishes and then we increase the intensity in approximately 50 mA increments. This is where the phenomenon of addiction or adaptation occurs, in which the sensory and muscle fibers become addicted to stimulation by the current because there is an increase in the valvular stimulus. Valvular stimulus in physiology is called the smallest possible value of a stimulus required to excite a fiber. That is, inhibition of the stimulation of the corresponding fibers is observed, because they become addicted to the specific intensity of the electroacupuncture current. Applying current to acupoints or muscle motor points when the intensity rises to the valvular stimulus level of 40 μA results in muscle stimulation, which is usually visible. It is essential that the intensity of the current should be increased by the potentiometer of the electroacupuncture machine slowly and gradually, so that the patient tolerates the increasing intensity well. In the case of a sudden increase in the intensity of the electroacupuncture machine, the patient will report a sudden sharp pain. When the intensity of the current increases to the point where muscle spasms are visible and felt, then we have stimulation (14).

The operating frequencies of electroacupuncture machines are among the main electrical parameters, because the beneficial effects of acupuncture depend on them. Frequency is measured in Hz, i.e. cycles per 1 sec. The frequency categories are divided into: low frequencies 0.1-10 Hz which are the best frequencies for stimulating the sympathetic system, medium frequencies 10-100 Hz which are the best frequencies for stimulating the parasympathetic system, high frequencies 100-1000 Hz, very high frequencies greater than 1000 Hz, which are not needed in daily practice except to achieve analgesia in surgical procedures. To induce analgesia during electroacupuncture anesthesia, high frequencies of the order of 2000 are used Hz close to the area where the operation is performed, while at the same time distant points are stimulated with low frequencies of 5-15 Hz. In general, frequencies of 1-35 Hz are usually applied to stimulate motor nerve fibers. The low frequencies of electroacupuncture, 2-4 Hz with medium intensity current are the most common in daily practice and cause analgesia with the release of endorphins. This is referred to as the opiate-dependent electroacupuncture pain relief system. The higher frequencies of 100-200 Hz have a similar effect by releasing serotonin and dynorphin. This is referred to as the non-opioid electroacupuncture pain relief system. When we apply an electric current with a frequency of up to 10 Hz on needles, which are close to motor points of muscles, then we have visible muscle contractions. If the frequency rises to 20 Hz, then muscle contractions are no longer visible, but muscle tetany occurs (15).

The current of electroacupuncture devices is also characterized by its emission rate. It is divided into continuous or intermittent rhythm. The rhythm of the current, when it is continuous but constantly interrupted, with a frequency of less than 4 Hz lasting 4 sec, while its inactive period is 4 sec, produces stimulation. However, in the event that the frequency is greater than 30 Hz lasting 4 sec, while the inactive period is 4 sec, it causes dispersion. The most successful rate of electroacupuncture is that of scanning (Dens-disperse). In this case, the rhythm is alternating-intermittent, with two different frequencies, a low 1-8 Hz and a high 30-100 Hz with intermediate pauses of 1-4 sec. Its main indication is the achievement of analgesia. With the scan it achieves, the tolerance effect, which is often observed in electroacupuncture, can be avoided. Electro-acupuncture pulse width Pulse width is the pulse duration of each waveform, emitted by the electro-acupuncture machines. The pulse range ranges from 100-500 μsec and can activate nerve and motor fibers, while at the same time it is well tolerated by patients. When we decrease the frequency of the electroacupuncture machine, then the pulse width automatically increases. That is, the lower the frequency of the

electroacupuncture machine, the greater the pulse width. When the pulse width increases, greater muscle wasting occurs due to its particularly intense effect on the muscles. On the contrary, when we reduce the pulse width, a greater effect is achieved on the sensory nerves, resulting in analgesia (16).

The traditional form of acupuncture involves selecting acupoints, according to the principles of Chinese Medicine, inserting fine needles into the selected points and manipulating the needles with certain techniques, such as twisting and lifting, to achieve “De Qi” sensation (arrival of vital energy Chi), which includes a feeling of heaviness, numbness, distension or warmth. "Chi" is one of the key concepts in Chinese Medicine and is considered to be the metaphysical understanding of the human body and body functions. According to traditional Chinese Medicine, Qi sustains human life and the movement of Qi enables physiological and psychological functions. Normal functions depend on the smooth movement of Chi. Acupuncture points are where Chi is in and out of the body to connect with nature. Acupoints are also where the body's Chi can be regulated by applying treatment such as acupuncture, moxa and massage to these points. Traditional Chinese Medicine books mention 365 points on the human body. Each point seems to have specific functions. With the introduction of modern technology and neurophysiological studies on acupuncture, some acupuncture techniques have been challenged and modified. Electroacupuncture is a typical example and was first applied in Japan and France between 1800. Instead of handling the needles by hand, they apply electrodes to the acupuncture points either directly or output it to an electronic device with the handle of a needle, thereby allowing the electric current to pass through these selected points. Obviously, there are many advantages to using Electroacupuncture. First, unlike manual needle manipulation, electrical stimulation can be easily controlled and reliably repeated. Second, an electric current has a number of parameters, which we can easily change. Different set of parameters may lead to different physiological effects and treatment may be more specific. For example, Electroacupuncture of different frequencies (2 Hz, 15 Hz, 200 Hz) has been shown to increase the release of the three types of opioid peptides (endorphins, enkephalins, dynorphins) respectively. In clinical practice, the use of alternating frequencies, such as 2/15 Hz, or 2/100 Hz, has been proposed to reduce opioid tolerance and enhance analgesia. Finally, it has been reported that electroacupuncture leads to a better analgesic effect, compared to classical acupuncture. Electroacupuncture can be performed with or without needles, activating traditional acupuncture points or choosing points that have a neural background, such as trigger points or tender points. The type of electroacupuncture can also vary depending on electrical parameters such as frequency, intensity, pulse duration and electrode size (17, 18-20).

Electrotherapy leads to stimulation of the sensory and motor nerves, and is especially used in the treatment of pain. Electroacupuncture mainly uses transdermal stimulation. Its action is mainly due to sensory stimulation, using low-frequency biphasic currents with low power (less than 5 W) and relatively short pulse duration (generally between 0.01 and 0.4 ms). With these parameters, any heat generated during the transfer of electrical energy to the tissues is easily dissipated and the oxidative and electrolytic action is minimal. Increased opioid release is thought to be the underlying mechanism for the analgesic effect of acupuncture and transcutaneous electrical nerve stimulation (TENS). Endogenous opioids are divided into endorphins, enkephalins and dynorphins. These three types of opioids have different affinities for the three types of receptors (21).

Electroacupuncture can increase the release of all three types of endogenous opioids, and the type of endogenous opioid peptide released depends on the frequency of the electrical stimulation. In rats, the analgesia elicited after electroacupuncture with a frequency of 2Hz at points C 6 and Sp 6 was abolished after the administration of naloxone at a dose of 1mg/Kg, while the analgesia elicited by the frequency of 100 Hz is abolished by the administration of ten times the aforementioned dose of naloxone. The correlated frequency of opioid release has also been confirmed in humans. The level of immunoreactive metecephalin and immunoreactive dynorphin A increases by 36% and 49% after applying TENS to the selected points with frequencies of 2 Hz and 100 Hz respectively. One study looked at the frequency of electroacupuncture at the clinical level. Subcutaneous injection of formalin in rats elicits a biphasic response, an early response due to direct stimulation of nociceptors lasting 5 minutes and a late inflammatory response occurring 20 minutes after injection and lasting 20-30 minutes. Sciatic nerve stimulation with 2 or 15 Hz produces an analgesic effect in both phases. Conversely stimulation with 100 Hz produces a strong analgesic effect only in the late phase. The results of this study confirm that the frequency-dependent analgesic effect of electrical stimulation can also be used at a clinical level to treat pain. Furthermore, in a comparison made between the postoperative application of electroacupuncture alone and that combined with preoperative application of electroacupuncture with 2 Hz, the latter led to a better analgesic effect in the late phase (22,23).

Pulse duration is another parameter of electroacupuncture analgesia. In a study Romita et al (1997) examined the effects of parameters of electroacupuncture, more specifically the withdrawal reflex after noxious thermal radiation in rats. Withdrawal latency is considered to be the pain threshold, with an increased latency indicating analgesia. Given a specific frequency (4Hz) and intensity (20 times threshold, 20T), electrical stimulation with 0.2 ms, 2 ms, and 5 ms reduced the latency. However, only electrical stimulation with 2 ms or 5 ms produces analgesia, lasting up to an hour.

The underlying mechanism linking analgesia to pulse duration may depend on the activation of different fiber centromeres. Electrical stimulation with a pulse duration of 2-50 μs makes the sensation of stimulation perceptible, but does not cause pain (sensory level). Electrical stimulation above 0.15 ms can cause muscle contraction and further activation of Ab fiber centromeres in the muscle (motor level). Electrical stimulation for more than 1.0 ms activates C fibers and leads to painful sensation (level of noxious stimulus). Analgesia induced by stimulation at the sensory level does not last longer than electrical stimulation, while analgesia induced at the motor and noxious levels lasts for hours. Thus Romita et al. (1997) with electrical stimulation of 2 or 5 ms apparently stimulate C afferent fibers and further activate endogenous nociceptive systems and produce this prolonged analgesic effect. Conversely electrical stimulation with 0.2 ms can activate Ad fibers. However, the author does not report whether this type of stimulation caused muscle contraction. In addition, the stimulation lasted only 20 minutes, much less than the required stimulation time, which is 30-45 minutes for the motor level stimulation. Thus transient analgesia can be induced through segmental pain control (24).

Intensity is perhaps the most important parameter in electroacupuncture analgesia. High-intensity electroacupuncture that produces a “strong but tolerable” or “strong but not unpleasant” sensation results in more satisfactory analgesia than low-intensity electroacupuncture. In rats, electrical stimulation at 4 Hz, and 10 times above the threshold that can cause muscle contraction (10 T), causes only a brief increase in the withdrawal latency, whereas electrical stimulation 20 times above the threshold causes analgesia lasting up to an hour. The use of electroacupuncture in postoperative pain control showed that high-intensity electroacupuncture (9-12 mA) reduced hydromorphine PCA (patient-controlled analgesia) requirements, as well as opioid adverse effects after surgery. In contrast, the effect of PCA and electroacupuncture with low intensity (4-5 mA) was not statistically significant, compared to that caused by PCA and "sham" electroacupuncture (the "sham" electroacupuncture is the application of needles at different points from those defined as the strictly selected acupuncture points) (25,26).

3. Conclusion

Electrotherapy leads to stimulation of the sensory and motor nerves, and is especially used in the treatment of pain. Electroacupuncture of different frequencies (2 Hz, 15 Hz, 200 Hz) has been shown to increase the release of the three types of opioid peptides (endorphins, enkephalins, dynorphins) respectively. In clinical practice, the use of alternating frequencies, such as 2/15 Hz, or 2/100 Hz, has been proposed to reduce opioid tolerance and enhance analgesia. Finally, it has been reported that electroacupuncture leads to a better analgesic effect, compared to classical acupuncture.

Compliance with ethical standards

Acknowledgments

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