Electroanalgesic Medicine Background / Theory

Dr. Michael A. Gramazio PhD, MD, MBBS, ScD, FACFE
Researcher and User of Electroanalgesic Medicine

The use of electrical signals for various medical treatments has been mentioned since ancient times with the earliest man made records (2750 BC) discussing the electrical properties and treatment potential of the Nile catfish, *Malopterurus electricus*.(1) Subsequent writings of Celsius, Oribasius, and other compilers describe medical treatment with electric fish by Hippocrates (420 BC) but little else until about 46 AD, at which time the Roman physician, Scribonus Largus, introduced the electrical capabilities of the fish into clinical medicine as a cure for intractable headache pain, neuralgia, joint inflammation, and gout.

In the 1700s, European physicians documented the use of controlled electrical currents from electrostatic generators for numerous medical problems involving pain and circulatory dysfunction. During that period, Benjamin Franklin also documented pain relief by using electrical currents for a number of ailments including frozen shoulder.

Today, the clinical use of electromedical modalities in both diagnosis and treatment is well documented with basic and physical science replete with references demonstrating the positive effects on patients for a myriad of medical conditions. (2) Transcutaneous Electrical Nerve Stimulation (TENS) treatment is a well documented, mild form of electromedical treatment that has been shown to provide pain relief by administering topical electrical stimulation through the skin with small electrodes. Physicians have proscribed T.E.N.S. treatment for home use. It is believed that the primary physiological mechanism of action achieved via standard TENS application is due to a direct *counter-irritation* of the central nervous system (CNS); the mechanism of action is consistent with the Gate Control Theory of Pain by Melzak and Wall.(3,4)

Electroanalgesia medicine, both at the stellate ganglion and the lumbar sympathetic region (paravertebral approach) (in a physicians clinical setting) have already been described in the literature. The reader is referred to the seminal paper by Robert Schwartz, MD titled “Electric sympathetic block: current theoretical concepts and clinical results.”(5) These blocks have been shown to be up to 75% effective and may be able to decrease a patient’s pain and increase functionality virtually without risk.

Advanced Generation of Electromedical Devices

A more advanced, medical device, known as an electroanalgesic medicine, appears to be much more potent in its ability to reduce or mitigate acute and/or chronic intractable pain conditions than conventional TENS technology (i.e. home unit). The major difference is higher frequency technology (used and procedure is performed by a physician in a clinical setting) over the older lower frequency TENS technology (1-250 pps / action impulses). Electroanalgesic technology incorporates high electronic digital signal with are much higher electrical frequencies (8,000 pps and above) using an advanced computer assisted High Definition frequency generator (HDfg) to reduce the hyper-irritated state of the nerves. This Electroanalgesic technology is continually varying the 1) carrier frequency, 2) and physician is continually changing the intensity (dosage) of the current to precisely match parameters delivered at the appropriate time.

Standard TENS technology relies on amplitude modulation (AM) of the electrical current being delivered to the body. The newer Electroanalgesic technology uses digital generated electrical signal delivered to the body as (high) frequency current (HFC). The theory is that this complex digital electrical system is changing so often that the nervous system cannot “learn” or accommodate to the administered high frequency digital signal and that the speed of the electric signal is so high that a complete depolarization of the nerve membrane occurs.

Specific Parameter Electrical Signaling

Specific parameter signaling is defined as selecting certain parameters to achieve two specific ends: 1) to more directly (and indirectly) focus their electro-physiological effects toward specific characteristics of the various nerve fiber types (A-alpha, A-beta, A-delta, C-fibers, etc.); and/or 2) to address the medical indications where certain “therapeutic mechanisms of action” are known to be useful in the treatment success of that particular indication.

These electrical variables include manipulation of the 1) carrier frequencies, and 2) sweeping of the carrier frequencies. With these frequency changes, the specific parameters of dosage (electrical signal energy amplitude) can be varied according to the changing frequency parameters. This adjustment is required because, as frequency increases, higher intensity is required for deeper tissue penetration and effect.(5) The increased dosage is tolerated by the tissues without patient discomfort or heat generation because the current perception threshold also rises. Sophisticated computer signaling is required for the rapid adjustments of amplitude as a function of the changing specific parameters.

Electrophysiology of the Neuron

It is well known that electric energy can be effectively used to relieve pain. Electric pulses of specific intensity and frequency can interfere with a neuron’s own electrical impulses, or action potentials, thereby disrupting its ability to transmit painful stimuli.(6) The functional unit involved in the transmission of, and reaction to, painful stimuli is the neuron, or nerve cell. Neurons have a membrane potential difference in the electric charge between the inside and outside of the cell. This membrane potential is expressed as a negative potential because the inside of the cell is negatively charged compared to the outside.

Application of specific parameter electrical stimulus makes the membrane potential more positive—a phenomenon called depolarization. Depolarization of the membrane to a certain threshold level induces a rapid firing of an action potential (action impulse). Once an action impulse has fired, a new one cannot occur until the membrane potential is stabilized back to its physiological resting potential. It should be noted that the action potential (impulse) is responsible for ALL transmission of bio-information, including pain signaling.

Once initiated by a distinct stimulus, the action impulse travels along the surface of the nerve axon and propelled by electrical energy generated locally by the depolarizing membrane. Thus, the impulse is both self-sustaining and self propagating. The impulse advances along the length of the nerve axon by electrical currents flowing between an active (depolarizing) membrane patch and adjacent resting (polarized) membrane surface. At rest, the interior of the nerve membrane is negatively charged with respect to the exterior.

At the height of depolarization, the nerve membrane briefly reverses its polarity, with the interior now being positive relative to the exterior. This initiates a flow of electric current between depolarized and adjoining resting portions of the nerve, which reduces the membrane potential (i.e. depolarizes) ahead of the active region.

As a result of these electrical depolarizing local current flows, sodium channels activate and sodium ions begin to stream inward. Soon, the inward sodium current exceeds the combined outward flows through potassium and leakage channels, the firing threshold is crossed, depolarization ensues, and an action potential is generated in the adjacent segment.(7,8)

Hypothesized Mechanisms of Electromedical Pain Management

Electromedical management of pain occurs primarily by these hypothesized mechanisms of action:(9)

1. **Counter-irritation**: The gate-control theory (described by Melzak and Wall)(4) explains that repeated exogenously-applied electrical signals perceived by the sensory nerve fibers affect the brain translation of endogenously produced (pain) signals. This is a neuron function-imitation or function-exhaustion effect that causes suppression of the sensation of pain.

2. **Release of neuropeptides**: This release occurs electrically by a neuron function stimulation effect upon the sympathetic nervous system and dorsal horn. This stimulation activates the release of endogenous pain-suppressing neuromodulators found in the central nervous system, i.e., endorphins, enkephalin, etc.(5,10)

3. **Inhibit Nerve fiber**: Multiple signals of transcutaneously-applied specific parameter electrical frequencies fall within the absolute refractory period of the cell membrane thus producing a sustained depolarization phenomenon. The traveling pain signal is stopped at the depolarized site (Wedensky Inhibition). (7,8,11) The nerve is sustained by the post hyperactivity depression (PHD) effect (discussed in a subsequent section).

Cell Membrane Hyperpolarization vs. Depolarization

Unlike a pure chemical nerve block, which occurs because of a sustained *hyperpolarization* of the cell membrane,(12) the regularly structured sustained depolarization of the cell membrane—intermittently produced by the electroanalgesic device—also stops the transmitted propagation of the nerve axon pain signal while allowing all cellular voltage-gated channels to function at optimum levels until their designated equilibrium point.(8) This difference is of paramount importance as the necessary metabolic activity of the cell is continued while the patient's pain suppression objective is facilitated. This normalization of neuron cell activity, partly achieved through increased cAMP second messenger activity, directly reverses pain feedback circuits and promotes healing.(2)

Long-term relief is accomplished by stimulating the body's own chemical messengers within the cells to correct or normalize their function. It is known to the medical community that injury and/or disease may cause the cells to not work efficiently in the necessary elimination of metabolic waste products (metabolites), and can directly prevent the circulation from bringing in necessary cellular oxygen and nutrients. This has a direct affect on the immune system response and the ability to heal (gap-junction response). It is hypothesized that the cells are so overwhelmed by the metabolic chemical imbalance that they cannot self regulate.(8)

A recent report suggests that similar neuropathic pain symptoms may have separate and distinct "pain producing mechanisms [which] are pharmacologically separable."(13) Since all voltage gated channels are affected by the parameter specific current, it is postulated that multiple effects may be seen on these separate pharmacologically responsive receptors, in this case the Na+ channels and NMDA receptor systems.

Critical Role of cAMP

It has been demonstrated that electroanalgesic medical treatment (sustained cellular depolarization) has a direct effect on the increase or normalization of cyclic Adenosine Monophosphate (cAMP)(14) which directs all cell-specific activity. With a normalized level of cAMP, the cells will return to their normal activity thus providing a necessary intra-cellular/extra-cellular relationship. In cellular physiology, the stimulated sustained depolarization that occurs has a direct effect upon the beta-adrenergic receptors, which are coupled to the stimulatory G protein. The initial response is an electrical conformational change of the cell membrane and activation of adenylyl cyclase, which converts ATP to cAMP.

It is well described and documented that cAMP directs all cell-specific activity, including repair of insulted tissue that causes the metabolic cascade (leaking arachidonic acid) and increased level of noxious pain mediators. Electroanalgesic medical treatment, as a pain fiber block procedure, produces signal energy stimulation and subsequent sustained depolarization increases (to normal) intercellular levels of cAMP.(7,8)

Post Hyperactivity Depression (PHD) Effect

Specific-parameter electroanalgesic treatment also produces a prolonged, hypo- excitable state of a nerve that arises from the application of a relatively short duration electric signal combined with a chemical blocking agent. This is referred to as post-hyperactivity depression (PHD effect) and clinical studies have shown that a 20-30 minute procedure may produce pain relief that lasts for hours, days, even weeks.(5) The C-fiber is more sensitive to the PHD effect than that of the A-fibers. Theories explaining this effect address the larger surface/volume ratio of small fibers compared to large fibers, making them more susceptible to trans-membrane potential effects resulting from extracellular ion concentration changes and known nerve fiber physiology concerning easier fatigue of small nerve fibers vs. large fibers.(5,10)

Effect of Dosage (Intensity) of Current

The ability of an electric stimulus to effectively penetrate body tissues and relieve pain is influenced by the current intensity (dosage), the carrier frequencies used, size and shape of specific electrodes employed, as well as anatomical placement. Increased current intensity (dosage) allows for increased depth of penetration and recruitment of deeper nerve fibers. Body tissue impedance, or resistance to alternating current, decreases with increasing current frequency; therefore, a higher current frequency requires less current intensity to overcome the outer skin and tissue impedance barriers. Since the perception threshold— defined as the lowest current intensity at which a patient reports any sensation at all (mild tingling, warmth)—increases with increasing frequency, a higher intensity current is permitted as frequency increases, thus facilitating the delivery of current to deeper tissues while avoiding pain sensation.(5,)

Conclusions

Without piercing the skin, physicians can now can administer effective Electroanalgesic treatments using a computer-assisted electronic high frequency generator (by NeuroMed) to reduce the hyper-irritated state of the nerves. This is accomplished by placing (patent pending) specific target surface electrode on the skin with the larger electrode on the opposing side of target area to help in the effects of pain relief and healing for the patient.

The strength of this targeted Electroanalgesic treatment is to reduce the ability of the affected nerves to transmit pain signals and, at the same time, promote healing by means of the depolarization effects on the nerve cells.

While the mechanism of action of Electroanalgesic treatments are unclear at this time, this technique has been successfully used and documented by physicians for a wide variety of refractory pain management problems. Long term advantages of this treatment regimen include:

1) potentially returning a PAIN patient to the work force

2) allowing the patient to perform activities of daily living with minimal pain

3) dramatic cost savings in both treatment and subsequent (lifelong) medication costs

4) avoiding interventions or surgery in a patient for whom every other conservative alternative has been exhausted or in a high risk medical patient

5) avoiding the probability (even with surgery) of chronic pain for this patient for the balance of his life (depending on the outcome of ongoing treatment)

The purpose of this clinical summarization report is to stimulate interest by Self-Insured companies, Third Party Administrators (T.P.A.), Workers' Compensation, Private Insurance Companies, and the medical community in general, in the use of electroanalgesic treatments to treat **PAIN.**

References

1. Kellaway Electromedical History and Development, Malopterurus Electricus. 1946
2. Woessner J. Electric Nerve Blocks. Weiner's Pain Management: A Practical Guide for Clinicians. 2006. Boswell M, Cole B, Eds. CRC Press. pp 1233-1242.
3. Melzack, Wall. Pain Mechanisms: A New Theory. Science. 1965. 150:171-179.
4. Burton C. Pain Suppression by Transcutaneous Electronic Stimulation. IEEE Trans Biomed Eng. 1974. BME21 (2): 81-88.
5. Schwartz RG. Electric sympathetic block: current theoretical concepts and clinical results. *J. Back & Musculoskeletal Rehab*. 1998. 10: 31-46
6. McQuay HJ and Moore RA. Transcutaneous Electrical Nerve Stimulation (TENS) in Chronic Pain. An evidence-based resource for pain relief. Oxford University Press 1998. Chapter 25.
7. Alberts B, Bray D, et al (eds). Molecular Biology of the Cell. Garland Publishing. New York. 1994. pp 523-540.
8. Darnell J and Lodish D (eds). Molecular Cell Biology Scientific American Books, New York. 1990. pp 771-777.
9. May HU, Sorgnard, R, and Gramazio M. Differentiated Electromedicine; Physicians Continued-Education Review. St. Luke's Hospital and Medical Center. Manila, Philippines. 1997.
10. Bonica J (ed). The Management of Pain. Lea and Febiger. Philadelphia. 1990. 1:365-1938.
11. Katz B. Experimental Evidence for a Non-Conducted Response of Nerve to Subthreshold Stimulation. Proc R Soc. 1937. 612.816.3:244-276.
12. Cousins MJ and Bridenbaugh PO (eds). Neural blockade: In Clinical Anesthesia and Management of Pain. Third Edition. Lippincott-Raven. Philadelphia. 1998. p 1177.
13. Gottrup H, et al. Differential Effect of Ketamine and Lidocaine on Spontaneous and Mechanical Evoked Pain in Patients with Nerve Injury Pain. Anesthesiology. 2006. 104: 527-36
14. Woessner J. Electric Nerve Blocks. Weiner's Pain Management, Boswell M, Cole E (eds.) 2006. pp 1233-1242.

Michael Gramazio Ph.D. was *working with a practicing interventional pain management physician. Address any correspondence to*. Michael Gramazio PhD. , drgramazioapma@yahoo.com

For more information,
write to us at:

Advanced Pain Medicine Association
3296 N. federal Hwy
Unit 39295
Ft. Lauderdale, FL 3339-8455

www.apmausa.org