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Review Article

A Practical Guide to Electroanalgesia and Laser Therapy in Acute and Chronic Pain Management

Nicholas A Kerna[1,2]*, Uzoamaka Nwokorie[3], Abdullah Hafid[4], Kevin D Pruitt[5], Raymond Nomel[6], Rashad Roberson[7], Sahalia Rashid[8], Fernand Jean-Baptiste[9] and John V Flores[10,11]

[1]*SMC–Medical Research, Thailand*
[2]*First InterHealth Group, Thailand*
[3]*University of Washington, USA*
[4]*Academy of Integrative Health & Medicine (AIHM), USA*
[5]*Kemet Medical Consultants, USA*
[6]*All Saints University, College of Medicine, St. Vincent and the Grenadines*
[7]*Georgetown American University, College of Medicine, Guyana*
[8]*All Saints University School of Medicine, Dominica*
[9]*Department of Biological Sciences, Florida Atlantic University, USA*
[10]*Beverly Hills Wellness Surgical Institute, USA*
[11]*Orange Partners Surgicenter, USA*

***Corresponding Author:** Nicholas A Kerna, (mailing address) POB47 Phatphong, Suriwongse Road, Bangkok, Thailand 10500. Contact: medpublab+drkerna@gmail.com.

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Abstract

Acute and chronic pain management is demanding for many healthcare professionals and their patients. Patients need relief. However, physicians must balance the therapeutic benefits of such therapy with the potential or actual adverse effects, including drug dependence, overdose and unintended death. The opioid crisis has reached epidemic proportions, resulting in considerable and unnecessary loss of life. This crisis and other adverse effects of pain medications necessitates applying an individualized, multimodal, and multidisciplinary approach to pain management. Effective non-pharmacological options should be considered and utilized to a greater extent—than they currently are—for more efficacious results for the patient and stem the tidal wave tide of drug dependence and addiction. Electricity has been used for pain relief since ancient times and is becoming more widely used today. Many healthcare providers have heard about electroanalgesia but may know little about how electroanalgesia works (its mechanisms of action), its indications and contraindications, what devices are available, and how to integrate electroanalgesia and electrotherapy into their practices for the benefit of specific, acute and chronic pain patients. This review aims to bridge this knowledge and know-how gap regarding electroanalgesia and electrotherapy by providing an overview of five types of electroanalgesia currently used clinically and how to integrate such therapies into practice; these five types being electroacupuncture (EA), ultrasound-guided acupotomy, transcutaneous electrical nerve stimulation (TENS), percutaneous electrical nerve stimulation (PENS) and peripheral nerve stimulation (PNS).

Keywords: *Analgesia; Busy Line-Effect; Electroacupuncture; Pain; Electrotherapy; Laser; Opioid Crises; Transcutaneous*

Abbreviations

AL-TENS: Acupuncture-Like TENS; DCS: Dorsal Column Stimulation; EA: Electroacupuncture; HHS: U.S. Department of Health and Human Services; HILT: High-Intensity Laser Therapy; LED: Light-Emitting Diode; LLLT: Low-Level Laser Therapy; NAALT: North American Association for Laser Therapy; PENS: Percutaneous Electric Nerve Stimulation; PNS: Peripheral Nerve Stimulation; SCS: Spinal Cord Stimulation; TENS: Transcutaneous Electrical Nerve Stimulation

Introduction

Pain is associated with physical, emotional and economic burdens and it significantly affects the quality of life in patients. Nearly 50 million US adults are estimated to suffer from chronic pain. It is projected that 19.6 million of these people have severe pain that interferes with daily life or work activities. The national economic burden associated with pain in the U.S. has been estimated between $560 and $635 billion annually [1].

Acute and chronic pain management poses a challenge for healthcare professionals. Patients with severe acute or chronic pain must get optimal relief with the prescribed therapy. However, physicians need to balance the therapeutic benefits of such therapy with the risk of adverse effects, including the development of drug dependence, overdose, and accidental death. These events can occur even when drugs are prescribed according to published clinical guidelines and are taken as directed [2].

The opioid crisis has now reached epidemic proportions due to the misuse of prescription opioids, resulting in many deaths due to overdose. This crisis necessitates using an individualized, multimodal and multidisciplinary approach in pain management [1]. Non-pharmacological options should be utilized to a greater extent in pain management regimens than they are currently used.

This review provides a practical overview of the available data on non-pharmacological approaches—electroanalgesia and laser therapy—which employ electric current and light, respectively—for managing pain. Physicians should better understand and consider these approaches for pain relief when clinically appropriate.

Discussion

Electroanalgesia: a historical perspective

Electricity has been used for pain relief since ancient times (approximately 60 CE). Roman physician Scribonius Largus recommended exposure to "electric fish" for pain relief in patients. Ancient records also point to the use of electric eels for treating pain. By the 18th century, therapeutic devices had replaced those ancient, natural sources of electricity.

These devices were designed to deliver static electric current to treat conditions ranging from headaches to cancer. In the 19th century, the devices were further modernized and the "Electreat" was developed; it enabled electricity therapeutically [3]. In the 20th century, the field of electrotherapy evolved, leading to more sophisticated methods and devices. Nevertheless, still, at least until the mid-1900s, electrotherapy had low acceptance in the healthcare realm.

In 1965, Melzack and Well proposed the "gate control theory of pain" [4]. According to this theory, stimulation of large-diameter afferent nerves due to non-painful stimuli (e.g. electric current) closes the "gate" in the spinal cord's dorsal horn, preventing the painful stimuli in the small-diameter afferent nerves from reaching the brain. The gate control theory of pain spawned further developments in electroanalgesia and neuromodulation for pain control [5].

Acupuncture has its roots in ancient China. Its modern variation in the form of electroacupuncture started to gain traction in the 1950s [6]. Acupotomy, developed by Professor Han-Zhang Zhu of China, is a modified form of acupuncture. The procedure utilizes a scalpel in addition to acupuncture needles [5].

The invention of modern-day pocket-sized, battery-operated transcutaneous electric nerve stimulation devices can be credited to Dr. C. Norman Shealy, an American neurosurgeon. An early version of the TENS unit was developed by Shealy to non-invasively screen patient candidates most likely to respond to neuromodulation before the invasive procedure of surgically implanting electrodes in the dorsal column of the spinal cord—a procedure termed dorsal column stimulation (DCS) in those days, and now referred to as spinal cord stimulation (SCS) [7]. Peripheral nerve stimulation was first applied nearly six decades ago to treat head and neck pain.

The original approach described by Wall and Sweet (1967) involved complex surgery and was associated with adverse effects. The method has undergone significant changes over several decades. As published by Deer, et al. (2016), the first clinical trial regarding a device, Stimrouter® (Bioness Company, Valencia, California USA) was designed to target peripheral nerves [7,8]. Percutaneous electric nerve stimulation is a modification of a method developed by North., et al. (1977) termed percutaneous electrostimulation [8,9]. It was applied to chronic low back pain syndrome, cancer, and other pain-producing disorders. Percutaneous electric nerve stimulation involves inserting acupuncture needle probes into the soft tissues or muscles, stimulating peripheral nerve fibers electrically. Conceptually, it may be considered as a combination of electroacupuncture and TENS [10].

Electroacupuncture (EA)

Electroacupuncture (EA) is a modified and modernized version of the ancient method of acupuncture. It is a minimally invasive procedure in which small crocodile clips are attached to the ends of acupuncture treatment needles (inserted at specific acupoints on the skin) are connected to an electroacupuncture device, providing continuous electric stimulations [10–12]. EA has demonstrated short-term and long-term benefits in managing pain (Table 1).

Acute	Chronic
In elderly patients undergoing spine surgery (reduced intraoperative anesthetic requirement and postoperative cognitive dysfunction)	Low back pain Fibromyalgia (moderate quality evidence—in combination with other therapies or stand-alone) Low-grade knee osteoarthritis

Table 1: *EA: Short- and long-term benefits in acute and chronic pain [13].*

Acupotomy

Acupotomy is a combination of traditional Chinese medicine and modern surgery. Studies show promising data on the application of this method in knee osteoarthritis [13,14]. Some studies have also suggested improved clinical efficacy and safety using ultrasound-guided acupotomy in cervical spondylosis, scapulohumeral periarthritis, lumbar disc herniation, knee osteoarthritis, and tenosynovitis. However, according to Qiu., et al. (2019), a more comprehensive evaluation of this method as a pain management modality is needed [14].

Transcutaneous electrical nerve stimulation (TENS)

Transcutaneous electrical nerve stimulation (TENS) is a non-invasive, convenient, and inexpensive method for managing pain [3]. TENS employs an electrical current to activate nerves via intact skin, which can be self-administered by patients with medical advice. The electrodes placed on the skin connect to the TENS unit, delivering an electrical current of varying pulse-widths, intensities, and frequencies—depending on the therapeutic indications and user tolerance. Low-frequency (< 10Hz) with high-intensity electrical pulse produces muscle contractions. High-frequency (> 50 Hz) with low-intensity produces paresthesia without muscle contraction. There are three ways in which TENS may be applied for neuromodulation:

- Conventional TENS may be used in treating pain with dermatomal distribution. High-frequency, low-intensity, small pulse-width electric current is used [10,15,16].
- Intense TENS primarily functions as a "counter-irritant". High-frequency and high-intensity current is applied for short periods.
- Acupuncture-like TENS (AL-TENS) may be utilized in patients non-responsive to conventional TENS. Low-frequency, high-intensity, long-pulse-width is used.

TENS is useful as an adjunct with other therapies or as a stand-alone therapy in several chronic and acute pain syndromes (Table 2). Contraindications to TENS include pregnancy, epilepsy, and the presence of a pacemaker implant. Also, electrode pads should never be placed over the eyes, transcerebrally, in the front of the neck, simultaneously on the anterior and posterior chest, internally, over broken skin or lesions, over tumors, directly over the spine, or on regions of severe paresthesia [10].

Acute	Chronic
• Cardiothoracic surgery (in combination with multimodal analgesia)	• Neck pain (in combination with neck exercises)
• C-section delivery	• Low back pain
• Myofascial pain syndrome (in combination with exercise)	• Osteoarthritis/Gonarthritis (Gonarthrosis)
	• Abdominal/ Pelvic pain
	• Temporomandibular (TMJ)

Table 2: *TENS: Modest short-term reductions in pain in acute and chronic conditions [3].*

Percutaneous electrical nerve stimulation (PENS)

Percutaneous electrical nerve stimulation (PENS) is a minimally invasive modality that is more labor-intensive and time-consuming than TENS. It is also more expensive than TENS as it requires qualified personnel to apply and operate the modality it [8,10]. Ultra-fine 32-gauge needles are inserted into the soft tissues or muscles to electrically stimulate the peripheral nerve fibers, corresponding to patients' pain symptoms.

PENS does not require electrode implantation. It stimulates dermatomes, myotomes, and or sclerotomes, corresponding to the sensory nerves at the site of pain stimuli—differentiating PENS from EA (EA involves stimulating specific acupoints, based on traditional Chinese medicine teachings). As this method delivers electrical stimuli near the peripheral nerve endings of an affected region and bypasses skin resistance, in some studies, it was shown more effective than TENS [10,17–20].

Rossi *et al*. (2016) demonstrated significant and long-lasting relief in neuropathic pain using the neurostimulator PENS therapy® device (Algotec Research and Development Limited, Crawley West Sussex, UK) [18]. Table 3 shows a list of conditions in which PENS has been found to provide pain relief.

• Myofascial neck pain (in combination with dry)
• Low back pain
• Sciatica
• Neuropathic pain
• Refractory headaches, particularly chronic cluster headaches, migraine

Table 3: *PENS: Short-term benefits in chronic pain [20].*

*Note: According to Roberson., et al. (2019): "Acupuncture is a time-tested method that has influenced the development of dry needling (DN) and electrical dry needling (EDN) to elicit a morphine-like effect without the harmful side effects of certain narcotics. [In specific conditions,] DN and EDN are cost-effective and less harmful to the patient in that they allow the body to provide its pain relief" [21].

There is an ongoing scientific debate regarding the nomenclature (and mechanisms of actions) of EA and PENS [20]. Cummings (2001) reported that some sources claim that EA and PENS are essentially the same, while other sources posit they are fundamentally distinct [22].

Peripheral nerve stimulation (PNS)

Peripheral nerve stimulation (PNS) is applied to the peripheral nerves corresponding to the area where pain relief is indicated. Theoretically, any focal pain area can be manipulated by stimulating the peripheral nerve supplying that particular dermatome.

According to Mainkar., *et al*. (2020), PNS requires implanting a stimulation electrode (connected to a battery source) about 1 cm from the target nerve. (Newer wireless implants have been developed which do not require the implantation of the pulse generator.) The procedure is performed under local anesthesia by trained neurosurgeons, anesthesiologists (with expertise in interventional pain medicine), or interventional radiologists [23].

Albright-Trainer., *et al*. (2020) noted that local infection at the stimulator lead placement site is a contraindication for this procedure. Also, patients with bleeding disorders require careful consideration due to the risk of hematoma formation. Infection, bleeding, hematoma formation, surgical site pain, and nerve injury are complications associated with PNS. Other device-related complications that physicians should be aware of are migration of the stimulator lead, lead fracture, and device malfunction [24].

Electroanalgesia: mechanism of action

The exact mechanism of how electrical stimulation of nerves leads to pain relief is not clearly understood, but various theories have been proposed. One of the earliest theories to explain analgesia produced by the electrical stimulation of nerves was the "gate control theory of pain" (Welzack and Well, 1965) [25].

Acute	Chronic
Neuropathic pain (*Guillain-Barre syndrome*) Oncologic pain	Migraine headache Cluster headache Post-stroke shoulder pain Chronic low back pain Pelvic pain Neuropathic pain of the extremities and trunk

Table 4: *PNS: Relatively effective [moderate- to high-level evidence) in the treatment of chronic pain [4].*

Experimental studies by Johnson (2007) suggested that low-intensity, non-noxious TENS paresthesia, generated by conventional TENS, relieves pain by a segmental mechanism. High-intensity TENS most likely acts via a counter-irritant effect as it activates the extra-segmental descending pain inhibitory pathways and diffuse noxious inhibitor controls. It may also block peripheral afferent impulses (busy line-effect) [25].

Pain relief achieved with TENS could also be credited to specific neurochemical activity. Low-frequency TENS may involve mu-opioid and 5-HT2 and 5-HT3 receptors. Also, analgesic high-frequency TENS activity may engage delta-opioid receptors and reduce aspartate and glutamate levels in the spinal cord [10].

Like TENS, electricity-induced neuromodulation of the peripheral nerves may be responsible for the pain-relieving action of the other electroanalgesia methods as well [15,23].

Laser therapy: a historical perspective

Laser therapy is a relatively new development compared to electroanalgesia in the field of pain management. In 1896, Dr. Niels Ryberg Finsen used concentrated light radiation for the treatment of diseases such as lupus vulgaris. He was awarded a Nobel Prize in 1903 for his contribution to medicine, thereby paving the way for new developments in the field of phototherapy. Theodore H. Maiman invented the laser in 1960. Mester., et al. (1967) demonstrated the effect of laser in biological systems, opening new pathways in using light for therapeutic applications [10].

According to White., *et al*. (2017): Low-level laser therapy (LLLT)—also known as cold laser therapy—with a wavelength of 600 to 990 nm and < 1W of power, has been adopted for pain management since the early 2000s. High-intensity laser therapy (HILT)—also known as laser heat therapy—with a wavelength of 660 to 1275 nm and 1–75W of power, is a newer development, emerging around 2011 [10]. Lasers emit monochromatic, non-ionizing, polarized, electromagnetic light radiation—non-invasive and focused (or coherent) [26]. The effect of laser light on biological tissues is not thermal but photochemical; it triggers cells' biochemical changes [26]. Newer LLLT devices use light-emitting diodes (LEDs) as the light source—non-coherent and emitted over a wide wavelength range. [10]

Administering laser therapy is a relatively simple process, which can be delivered by trained technicians [10,25,26]. Table 5 lists the various types of acute and chronic pain conditions for which laser therapy has been examined.

LLLT: Acute and chronic pain management	HILT: Acute and chronic pain management
• Acute and chronic pain related to the herpes virus	• Low back pain related to the herpes virus
• Osteoarthritis	• Osteoarthritis
• Low back pain	• Hemophilic arthropathy
• Superficial postoperative pain	• Postoperative pain
• Neck pain	• Shoulder pain
• Opioid dependency	• Opioid dependency
• Headache	• Myofascial pain syndrome
• Plantar fasciitis	• Fibromyalgia-related pain
• Dental pain	
• Trigeminal neuralgia	
• Mucositis-associated pain	
• Wound repair	
• Muscle injury pain	
• Shoulder pain	
• Carpal tunnel syndrome	

Table 5: *Chronic and acute pain management applications for laser therapy [26].*

Note: The list of acute and chronic pain conditions in Tables 1–5 is representative, not comprehensive. Tables 1–5 were produced by members of the Graphics Department of Dr. Nicholas A Kerna's Research Lab, using data from several sources [10,25–27].

Low-level laser therapy (LLLT)

Low-level laser therapy employs light—either laser or light-emitting diode (LED)—in the red to near-infrared region of the spectrum, as these wavelengths can penetrate the skin and soft and hard tissues. Light is applied to the injury or pain site for 30 to 60 seconds, multiple times in a week for several weeks [10].

The North American Association for Laser Therapy (NAALT) recommends specific precautions with laser therapy. Laser beams should never be directed at the eyes and safety goggles should be worn. The laser beam should not be applied to areas of primary carcinomas or secondary metastases [26–28]. However, laser therapy may be considered for palliative treatment in terminally-ill cancer patients. The laser beam should never be directed at the developing fetus in a pregnant woman. Extra care should also be taken in photosensitive epileptic patients as the laser beam may precipitate seizures [26].

Hayes Jr., *et al*. (2020) reported that "the primary effect of LLLT is stimulating and enhancing mitochondrial and intracellular functions and reducing pain and concurrent inflammatory reactions" [29]. The researchers further stated that "the administration of LLLT is comfortable (since no significant heat is produced) and is extremely safe when administered by trained professionals. Furthermore, laser therapies are safe for use in patients with pacemakers and metallic implants, including prosthetic joints and limbs" [29].

High-intensity laser therapy (HILT)

High-intensity laser therapy (HILT) uses lasers that produce up to 75W of power and operates up to 1275 nm wavelength. Phoenix Thera-Lase device (Phoenix Thera-Lase Systems, Dallas, TX, USA) is a type of high-intensity laser device approved by the US FDA. Owing to its enhanced power and reduced absorption by melanin and hemoglobin at these prescribed wavelengths, the high-intensity laser beam penetrates deeper into the soft tissue [10].

Laser therapy: mechanism of action

It is posited that LLLT acts at a cellular level, triggering multiple signaling pathways through mitochondrial stimulation. The nociceptors' peripheral nerve endings lie in the epidermis' superficial regions, well within the penetration depth range of the light wavelengths used in LLLT [1].

The cumulative analgesic action of HILT has been credited to multiple mechanisms of action: reduced transmission of pain stimulus through neuromodulation, increased production of morphine-like substances, increased blood flow, vascular permeability, and cell metabolism [30].

Pain (acute, chronic, nociceptive, or neuropathic) is an unpleasant sensation, encompassing the spectrum from mildly annoying to severely debilitating, depending on its etiology. This variance makes treating certain kinds of pain a daunting task, suggesting a holistic management approach.

It is crucial that physicians consider not only the pain etiology but also other factors, such as commorbities (medical history, age, weight, allergies), social factors (education, economic condition, social support, ethnicity), and psychological factors (trauma, stress, childhood history, coping ability)—before devising a comprehensive and individualized treatment plan for pain management [8].

Patient access to healthcare facilities and third-party reimbursement policies should also be considered. Opioids, often prescribed for acute and chronic pain, have led to a significant rise in prescription drug misuse [30]. An epidemiological study by Eriksen., *et al*. (2006) showed that opioid therapy for chronic pain fails to meet outcome treatment goals (optimal pain relief, improved quality of life, and improved functional capacity) in non-cancer patients [15,16].

Physicians are encouraged to consider, when clinically appropriate, non-pharmacological methods for managing pain. Moreover, one of the gaps in acute and chronic pain management—identified by the Pain Management Best Practices Inter-Agency Task Force Report, prepared by the US Department of Health and Human Services (HHS) in 2019—was the underutilization of multimodal, non-opioid therapies in the perioperative, musculoskeletal, and neuropathic injury settings. Many studies have confirmed positive short-term treatment outcomes with alternative approaches, such as electroanalgesia and laser therapy [1,31].

A lack of well-designed long-term outcome studies has limited non-pharmacological agents in the clinical setting. Low reimbursement by third-party providers also adds to the underutilization of these therapies. Specific studies have demonstrated that using electroanalgesia or laser therapy combined with conventional pharmacological approaches improve treatment outcomes (psychological well-being, ability to return to work, sleep quality, activity level) in select patient populations [1,15,32–35].

There is an added risk of oral analgesics being discharged in breast milk in women prescribed these medicines after cesarean delivery. The use of practical and specific non-pharmacologic approaches in such cases is deemed beneficial [16]. Adjunct treatment with these alternative modalities may also reduce analgesic rescue medication [12] or the intraoperative dose of anesthetic during surgeries [36–38].

Conclusion

The application of electroanalgesia and laser therapy is ever-evolving. Several studies have shown them to be viable non-pharmacologic options in pain management. Despite certain research limitations, like small sample sizes, the presence of some biases, the lack of appropriate placebo controls, and other methodological issues [34,35], most studies suggest that electroanalgesia and laser therapy are useful interventional modalities in pain management. Other studies have questioned the efficacy of these alternative approaches [10]; however, there is a consensus that they are relatively safe, with only a minimal risk of side effects. More well-designed, long-term outcome studies seem indicated so that these non-invasive and minimally-invasive therapies may be effectively and fully utilized in pain management regimens.

Conflict of Interest Statement

The authors declare that this paper was written in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

Supplementary Note

Most third-party providers consider the methods and modalities described herein as “investigational” and, thus, do not reimburse for the treatment with such—with a few exceptions.

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