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Electric Nerve Blocks

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INTRODUCTION

Those who have been shocked by lightning, an electric fence, or a household socket know that numbness occurs in the shocked body part(s), resulting from interruption of pain and sensory signals to the brain. That nerve blocks can be done with electricity is scientifically established. Performing nerve blocks with electricity is well enough accepted that two medical dictionaries describe nerve blocks as follows:

> *Gould's* (Gennaro et al. 1984): "nerve block. The interruption of the passage of impulses through a nerve, as by chemical, mechanical, or *electrical* [italic added] means."

> *Taber's* (Thomas, 1997): "nerve block. The induction of regional anesthesia by preventing sensory nerve impulses from reaching the central nervous system. This is usually done on a temporary basis, by using chemical or *electrical* [italics added] means."

These definitions, which accept electricity as an analgesic agent, make the concept and reality of nerve blocks being achieved scientifically accepted.

Electric nerve blocks (ENBs) involve introduction of an alternating electric current (AC) into the patient's body to interrupt the nerve impulses along pathways so that the perception of pain is decreased beyond the time of the actual treatment itself. Use of ENBs is not thought to conflict with currently accepted treatments for any part of the body, in a purely medical sense. ENBs are useful supplemental tools for patients who have pain.

NERVE BLOCKS IN GENERAL

Nerve blocks generally involve the introduction of an anesthetic agent to interrupt nerve impulses (Gordy et al., 2002). Nerve blocks provide analgesia and anesthesia. This entire volume explores the full range of therapies for the management of pain; analgesia provided by nerve blocks produced with electricity is the focus of this chapter.

THE ORIGIN OF NERVE BLOCKS FOR PAIN

Nerve blocks were originally done mechanically to facilitate local surgical procedures. Local and general anesthesia as part of surgical procedures became more sophisticated over time (Brown & Fink, 1998). It was noted that little or no pain was perceived after providing nerve blocks. Consequently, physicians began to use nerve blocks for better pain control. In both anesthetic and analgesic application, the resultant pain relief provided a window of opportunity for the surgical procedure and for healing, respectively.

Because most nerve blocks were done with chemicals, most practitioners usually thought of chemical injections in connection with nerve blocks. Because anesthesia usually included analgesia, nerve blocks were subsequently used to promote pain control in situations where general anesthesia was considered unnecessary or undesirable.

"THE BODY ELECTRIC" (BECKER & SELDEN, 1985)

During the 20th century, electrical devices became generally accepted in medicine, initially for diagnostics. Most

are familiar with electrocardiography (ECG), electroencephalography (EEG), and electromyography (EMG), including surface EMG (sEMG) and nerve conduction velocity (NCV) studies. Electrooculography, electroretinography, electronystography, electrocochleography, skin galvanics, and various evoked potentials are more specialized, accepted, although less well-known electrodiagnostic procedures (Northrup, 2001).

Many have been clinically treated with electricity. Defibrillation, used in emergency situations to reestablish cardiac activity when fibrillation occurs, involves the passage of an electrical current through the chest. Lower back pain often responds to transcutaneous electrical nerve stimulation (TENS) therapy and other electrotherapeutic techniques as part of overall treatment. Electroconvulsive therapy (ECT) for depression, spinal cord stimulators (SCS)/dorsal column stimulators (DCS) for chronic pain control, bone growth stimulators after orthopedic surgery, neuromuscular stimulation for disuse atrophy, and a number of other electrotherapies are a few examples of the currently used electrical techniques in modern medicine. TENS devices, as designated by the FDA, also include high-voltage galvanic stimulators (HVGS), neuromuscular electrical stimulators (NMES), interference stimulators, and various transcranial stimulators (e.g., the Alpha-Stim® devices and the Liss Transcranial/Body Stimulator®). Most of these electrical devices have been approved by the FDA as safe and efficacious and are allowed for certain indications for use. Other electromedical treatments include:

- Thalamic stimulation
- Electroacupuncture
- Auricular acupuncture

While generally safe, these electrical procedures require a precise understanding of the patient's overall medical condition for best results and to avoid possible undesirable side effects. As with anything in medicine, ENBs have a specific medical indication and are *not* "cure-all" procedures. Most of the side effects are directly related to local changes to blood flow, probably occurring with the blocking of pain nerve impulses with electricity because efferent C-fibers to local arterioles are also blocked.

ANESTHESIA OR ANALGESIA

Leak (1992) nicely differentiated the creation of numbness, i.e., anesthesia, and the interruption of pain signals, i.e., pain nerve block or analgesia. As stated, anesthesia usually includes analgesia, but not the other way around. When doing nerve blocks for pain, anesthesia can markedly interfere with normal sensory function and, therefore, put the patient in unnecessary danger.

Surgery has been done by blocking sensory nerve impulses with electricity (Hardy et al., 1961). Electroanesthesia and electroanalgesia have been used in Europe (Gadsby, 1998) and in the United States (Racz et al., 1992). If the electrodes are properly placed to perform nerve blocks, the clinical effects are not due to only electrical stimulation that would "stimulate" sensation and/or pain. FDA-accepted electrical devices used for ENBs do not provide enough current energy to cause frank anesthesia.

BACKGROUND

Using electricity for medical treatments occurred in ancient times (Rossi, 2003). Thousands of years ago ancient cultures used electricity-producing animals (electric eels and rays) to administer electricity to sick (including those in pain) citizens as medical treatments. Electrical machines were popular with American doctors for therapeutic purposes until 1907, when a campaign was initiated suggesting that the use of electricity as a medical treatment was quackery. Negative publicity resulted in most practicing physicians discontinuing the further use of electricity in their practices. There still remains some sense of illegitimacy about ENBs even into the 21st century.

ELECTROTHERAPY

Electrotherapy used in some way to treat pain is frequently mentioned in books on electrotherapy (Kahn, 2000; Kitchen, 2002; Nelson et al., 1999; Robinson & Synder-Mackler, 1995; Simpson, 2003). Mechanisms for relieving pain are suggested, but nerve blocks are seldom mentioned directly. The best reason for pain relief from electrical stimulation, separate from ENBs, is the release of endorphins as pain modulators, and increased circulation and its relationship to muscle relaxation (Kitchen, 2002), explaining the residual pain relief that occurs following ENBs.

Interestingly, most patients in pain seldom mention any lasting effect from traditional TENS units or electrostimulation (E Stim) treatments. Interferential and HVGS units often provide longer-lasting relief. This pain relief makes sense in the context of this chapter because the carrier frequency of interferential therapy is 4,000 Hz (cycles per second, or cps), which may result in neuron blockade. The high energy produced by the HVGS units potentially crosses the nerve cell membrane to activate cyclic adenosine monophosphate (cAMP); in other words, penetrance occurs via high energy rather than via high frequency.

EVIDENCE FOR NERVE BLOCKS WITH ELECTRICITY

Most physiology textbooks provide a basic description of the electrophysiology of human cells and tissues. Charman (2002) provides a short review of the "electrical properties of cells and tissues." Becker and Seldon (1985) has provided significant scientific evidence that the body is truly an electrical organism. ENBs involve the use of electricity in medicine (Kane & Taub, 1975), and the term itself was probably first used by Dr. Jenkner in his 1995 book, *Electric Pain Control* (Jenkner, 1995).

Schwartz (1998) provided a theoretical basis for ENBs. Schwartz (1998) and Hans Jurgens (1999) presented plausible mechanisms by which nerve blocks and curative phenomena could occur via electric currents applied to the human body. Clinical experience based on these theories suggested that nerve blocks do occur with electricity (Woessner, 2002b).

Stimulatory frequencies, the frequencies below the refractory frequency of the nerve (the maximum frequency that stimulates a nerve to fire), are basically employed for electrotherapeutic techniques (Hans Jurgens, 1999). Electrotherapeutic treatments are usually much below 500 Hz (cps) (Kitchen, 2002).

De Domenico (1982) and Goats (1990) suggested that interferential therapy provides a "physiological block of nociceptive fibres." This description is largely due to the carrier frequencies (approximately 4,000 Hz), which result in greater tissue penetration, rather than just the tomographic effect of these synchronized, but offset carrier frequencies, which produce the "beat" or interferential frequencies (10 to 150 Hz). Multifacilatory frequencies described by Hans Jurgens (1999), the frequencies above the refractory frequency of the nerve (usually 4,000 to 20,000 Hz), are obviously not functioning via nerve stimulation because the target nerve can fire only once at frequencies less than the refractory frequency (which can be thought of as being around 1,000 Hz).

The frequencies used for ENBs likely carry the electrical signal and energy inside of the nerve cells and likely stimulate the cAMP (Brighton & Towensend, 1986; Knedlitscheck et al., 1994) because of the lower impedance at these frequencies (Schwartz, 1998). At sufficient levels, electrical energy has an intraneuronal effect on cAMP activity; cAMP is an intracellular second messenger, which merely passes on "permission" for the cell to do something. Knedlitschek et al. (1994) actually showed that intracellular cAMP is depleted after being subjected to 4,000 Hz of electrical energy at adequate voltage.

cAMP is utilized and decreased in absolute amounts as it relays the message to open the voltage-gated channels and start other metabolic activity to the intracellular organelles (Wilson-Pauwels et al., 1997). These later phenomena can be described as direct normalization of the cell function, which directly reverses sensitized pain feedback circuits and possibly promotes healing. As whole books are written entirely on the role of cAMP (Rasmussen, 1981), suffice it to say that ENB procedures are hypothesized to "shock" voltage-gated channels open and stimulate metabolic pathways to normalize pain nerve function.

Simply stated, AC frequencies greater than the rate a nerve can fire, i.e., greater than 1,000 Hz, specifically, in this case 20,000 Hz, have been shown by Knedlitscheck et al. (1994) to stimulate utilization of cAMP. In fact, Kilgore and Bhadra (2004) have shown that nerve block via depolarization does occur at 2,000 to 20,000 Hz. Wali and Brain (1990) showed more sustained blockade. Wyss (1967, 1976) clearly showed that depolarization is sustained with the application of these currents, specifically 4,000 Hz. The author's clinical experience, as shown in the table and histograms below, strongly suggests the analgesic, likely via nerve block, is indeed achieved with electricity (Woessner, 2002a).

Especially for electric and chemical nerve blocks that are thought to block sympathetic fibers, thermal gradients comparing side to side can be helpful to document the effectiveness of the block of these fibers, because blocking the efferent sympathetic C-fibers to the small arterioles results in distally increased circulation, therefore, increased skin temperature. However, temperature changes (e.g., increased temperature on the blocked side) are not a direct measure of afferent pain nerve function. With greater blood flow, we expect decreased edema and temperature increase.

Whether these phenomena occur or not may provide evidence that a proper nerve block has been achieved, but the basic purpose of these ENB procedures is to relieve pain temporarily or even permanently. With decreased pain, functional improvement is expected. Clinically, these positive results are seen (Woessner, 2002a). Providing "proof" is time-consuming and is often requested by the payers, yet the change in perceived pain and the duration of that change are most important for the patient.

The author has performed about 4,000 ENBs. The results of more than 3,500 ENB procedures are shown in Table 83.1 and Figure 83.1. The percent of pain relief as indicated by the patients' verbal response scores (VRS) was noted just before and after the procedure (Table 83.1).

The determination of patients' perception of pain after the electrodes were removed likely represents the pain relief effect. The duration of relief is more a reflection of the inverse severity of the causative pathology resulting in nociceptive rather than neuropathic pain and may explain the lack of any relief in a few cases.

Only a few patients get complete, immediate, and permanent relief of pain in one treatment. Over half of the patients achieve a successful outcome (defined as maintained improved function and satisfying, to the patient, level of perceived decreased pain) during a course of 5 to 15

TABLE 83.1
Categories for Analysis of the Pain Reduction in the 3,508 ENB Procedures Done in the Author's Clinic on More Than 300 Patients from 1996 to 1998

% Pain improvement	No. of treatments	Percent in category
Less than 0	24	1%
Exactly 0	298	8%
1 to 24%	426	12%
25 to 49%	590	17%
50 to 74%	791	22%
75 to 100%	1379	40%
Total	3508	100%

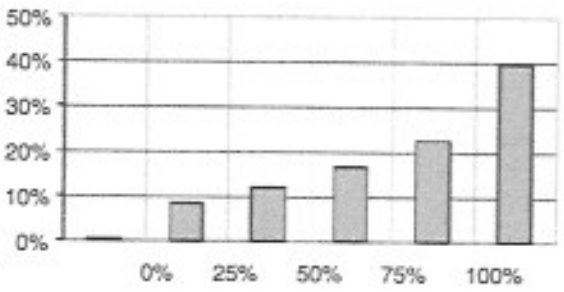

FIGURE 83.1 Of 3,508s ENB procedures done in the author's clinic on more than 300 patients from 1996 to 1998, clear reduction in pain perception well after the electrodes were removed, i.e., 25% improvement or better, occurred in 91% of the treatments, among which 40% perceived no pain at all after the treatment. (From J. Woessner, 2002, *Practical Pain Management*, 2(2), 19–26. Reproduced with permission.)

treatments. Individual variations occur with some short-term relief occurring in more than 80% of these cases and 20% obtaining complete immediate relief. The average duration of pain relief is from 1 to 3 days. Some obtain only a few hours of relief; the occasional subject who is essentially cured in one or more treatments may have purely neuropathic pain. Recurrence of pain depends on actual pathology, patient activities, and concomitant treatments. A successful course of treatment usually shows gradual improvement. Fewer than 2% of patients had worsened pain and discomfort because of toxic substance release.

ENB VERSUS E. STIM: WHAT ARE THE DIFFERENCES?

The term *electrotherapy* is avoided in this chapter. Electrotherapy uses stimulatory frequencies below the maximum firing rate of the pain nerves and is based on mechanisms for providing pain relief, but does not block or interrupt pain signals along the two types of pain nerves per se, except possibly if we focus on the carrier frequencies (4,000 ± 100 Hz) in interference therapy, rather than on the beat (interference) frequency (Kitchen, 2002; Palmer & Martin, 2002) (Table 83.2).

TABLE 83.2
Procedural Comparisons of ENB vs. E. Stim.

ENB	E. Stim
64XXX	97XXX
Physician code	Therapist code
Physician controlled	Therapist controlled
Doctor present	No doctor
Diagnosis based	Body area based
Pathology specific	General condition
Multifacilitory*	Stimulatory
Analgesia	Electrical stimulation
Voltage gate alterations for block	Repeated nerve stimulation
?Signed consent	Consent, but not signed
Hundreds of dollars billed	Tens of dollars billed

* Multiple modes of action; decreased perception of pain also produced by circulatory changes, endorphin increases, secondary muscle relaxation, and other physical chemistry phenomena.

Note: From A. Hans Jurgen, 1999, presented at American Academy of Pain Management's annual clinical meeting, Las Vegas, Nevada. Reproduced with permission.

ELECTRIC (ENB) VERSUS CHEMICAL NERVE BLOCK (CNB)

There are some general nerve block concepts that require elucidation (Table 83.3).

The main difference is that local or regional analgesic chemicals close the voltage-gated channels so that pain nerves remain in a hyperpolarized state. With ENBs, synthesis of available information suggests that intracellular cAMP is stimulated to hold the voltage-gated channels open; a normal polarized state cannot be achieved and, therefore, the nerve cannot be stimulated to fire.

MECHANISM OF ENB ACTION

As for ENB frequencies, the author has mostly used frequencies between 4,000 and 20,000 Hz. No set terminology is applied to these frequencies, although Wyss (1967) did call them "middle frequencies." In this frequency range, nerves, particularly pain nerves, are not expected to repeatedly fire because they cannot achieve a firing potential, which is called sustained depolarization (Wyss, 1976). As indicated above, these frequencies do stimulate cAMP (Knedlitscheck, et al., 1994), which in turn opens voltage-gated channels in the pain nerves (Wilson-Pau-

TABLE 83.3
Evaluative Similarities and Differences of ENBs Compared with Chemical NBs

	ENB	CNB
Invasiveness	yes[a]	yes[b]
Site of action	voltage gated channels	voltage gated channels
Locational specificity	target nerve	target nerve
Physician involvement[c]	yes	yes
Documentation	procedure note	procedure note
Side effects	multiple + burns	multiple + anaphylaxis
FDA control	yes	no
Safety	very safe	safe
Patient perceptions	try and see	ultimate, short of surgery
Consent necessity	yes	yes
Effective[d]	50–90%	50–90%
Curative[e]	yes	yes
Cost	high	very high

[a] Just as high voltage currents and lightning.
[b] Just as microneedles and high pressure streams.
[c] Decides dose and target nerve.
[d] Very difficult to define. Author's general impression is similar; in both cases, depends more on the pain cause and the nociceptive pathology; neither is a cure-all.
[e] Both are basically cover-up procedures that should be part of a comprehensive treatment plan.

wels et al., 1997). These two mechanisms, hyperpolarization by chemicals and sustained depolarizataion by middle frequency currents, seem to explain the prolonged pain relief that occurs in most cases of chemical and electric nerve blocks. When prolonged relief does not occur, the pain stimulator, nociceptive or neuropathic, is overwhelming the nerve block action, whether induced chemically or electrically. If Waxman et al. (2001) are correct, the site of action is at the sodium voltage-gated channels. The curative action must then in part be downregulation of the increased number and density of the sodium channels.

The 8- to 20-minute time of onset is also similar between chemical and electric nerve blocks. The C-fibers are affected earlier than A-delta fibers and recover more slowly (Hadzic & Vloka, 2004). Myelin is less conductive than nerve tissue, explaining the greater effect of both local anesthetics and electricity on smaller and less myelinated pain nerve function.

ENBs treat pain, not necessarily the underlying pathology, unless the main problem is neuropathic. Nerve blocks are designed to provide a "window of opportunity" for the body to heal itself and/or for therapy or surgery benefits to be realized.

APPLICABLE NEUROANATOMY

The identified and recognized nerve can reasonably be affected in two ways, suggesting two different ways to approach electrode placement. An ENB can be achieved by treating across the nerve or along the nerve. The pain practitioner must know the anatomic course of the nerve and its distal distribution to correctly place the electrodes to fulfill regulatory and treatment needs, especially when dealing with a predominant A-delta fiber pain problem.

Theoretically, it is best to include the broad distal distribution of pain nerve endings, particularly of the A-delta fibers; these distributions also include unmyelinated free nerve endings in traditionally mapped nerve distributions (supported by Fischer, 2002). Even so, the distal distribution of sympathetic C-fiber free nerve endings are not well documented, but may be consistent with sclerotomal pain patterns that do not completely follow dermatomal patterns. Diagnosing the location of the pathology is difficult and may be better understood by considering one of the variable pain referral patterns discussed by Woessner (2003); specific electrode placement should be varied accordingly.

RELEVANT NEUROPHYSIOLOGY

The time from initiation of a nerve impulse until the time the nerve is ready to fire again is the refractory time of that nerve. If that time is 1/1000 of a second for A-delta (and 1/500 of a second for C-fibers) that nerve can fire no more than 1,000 times per second (and 500 times per second, respectively) (Ganong, 2001).

If a typical TENS unit is applied to that nerve at 100 cps, that nerve will be stimulated to fire and allowed to rest 90% of the time for the A-delta fibers. If this 100 cps

alternating current is applied to a pain nerve, then stimulation would be expected to make the pain worse, not block the pain signal. Other mechanisms of pain relief are not precluded (Kitchen, 2002).

DIAGNOSTIC CONSIDERATIONS

While sensory nerve testing may support the C-fiber and A-delta fiber pain manifested by complex regional pain syndrome (CRPS I) (reflex sympathetic dystrophy) and CRPS II (causalgia), these diagnoses are basically deduced from the patient's history, physical examination, and clinical observations (Woessner, 2002b). The burning pain, characteristic of these sympathetically maintained pain syndromes, comes from the C-fibers that coat the nerve trunks and other tissue planes while the sharp, lacinating pain comes from the A-delta fibers.

TREATMENT CONSIDERATIONS

Electromedical treatments often make more sense clinically than do chemical nerve blocks, especially when it is difficult to locate the pathology or when the pathology is widespread (e.g., up and down the length of the involved nerve). ENBs are potentially the best treatment, if the pathology is believed to be neuropathic in nature.

Treating neuropathic pain with ENBs is logical in many pain conditions, remembering that ENBs are not "cure-alls" and must be incorporated into a comprehensive treatment plan. It is potentially easier to proceed in advanced cases because most other treatments often do not work and/or are too medically risky. ENBs should be used earlier to avoid these risks.

When other therapies fail, electromedical treatments are potentially worthwhile and carry lower risk for patients. If the electromedical treatments work, then certain diagnoses are likely supported, and the treatment plan and ultimate prognosis may be better determined. When local widespread inflammation is involved, it is necessary to bathe nerves along tissue planes throughout the area of pain with electric current. However, this technique may not be successful in achieving pain relief, if it follows multiple chemical blocks in which scar tissue results, causing relative insulation. For these situations, an "electromedical Bier block," which involves bathing the whole limb with electricity of the frequencies mentioned above can be done with minimal risk.

TREATMENT INDICATIONS

Theoretically, ENBs can be used in any pain condition, but should be more curative in neuropathic pain conditions. Because most pain conditions have both nociceptive and neuropathic components, treatment decisions to use ENBs are complex, change over time, and may be different among individual patients. While ENBs may help in predominantly central pain conditions, the mechanism of action is not neuron blockade. In pure nociceptive conditions, any relief achieved should be more temporary. In the author's experience (Woessner, 2002b), myofascial pain is not neuropathic; any pain relief from ENBs is likely to be short lived.

Pure neuropathic conditions, without maintaining pathology, may be corrected/cured in one or a few ENB treatments; in other words, neuron blockade is achieved via cAMP opening the voltage-gated channels, and cure is also achieved by the cAMP as a second messenger, which promotes normalizations of pain nerve cellular function.

In addition, with restrictions mandated by the FDA for relative safety, ENBs will work better for localized peripheral conditions. For example, local, single-level radiculitis (irritation without obvious mass pathology) and mononeuropathies are the ideal candidates for ENBs. Fibromyalgia and diabetic pain are more difficult and relief is more likely temporary because the disease is so widespread that the current density is diluted.

An obvious treatment strategy would be to do multiple serial treatments on different parts of the body or use multiple machines; the former would be very time-consuming, and the latter is logistically complex and the cost would not likely be justified by adequate reimbursement.

THE ENB PROCEDURE

With neuroanatomical knowledge, many nerves may be blocked. Relevant for both chemical and electric nerve blocks, whether done across or along the nerve, is that the impulses from the populations of pain nerve endings are blocked. See Woessner (2002a) for a specific example of how an electric sciatic nerve block can be done.

Whether blocking across the nerve or along the nerve, a relatively small electrode is usually placed where a needle for a regional chemical nerve block would be inserted. A relatively larger electrode is placed either directly across the body part through which the target nerve transits or distally in the target nerve distribution field of pain nerve endings.

The full details of performing ENB procedures are beyond the scope of this chapter, but discussion of electrical frequency and machines that are capable of producing electric nerve blocks are presented below. Practitioners doing ENBs must be able to

- Diagnose neuropathology
- Develop a treatment plan with the patient that may include ENBs
- Use appropriate equipment
- Correctly place the electrodes
- Document what was done, including pre- and post-treatment pain intensity scores
- Provide supplemental medical advice and care

Surface Landmarks

Palpating the surface anatomy and visualizing underlying structures are essential for optimizing electrode placement. Accommodation is needed for underlying low conducting tissue and electric current pathway elongations. Accomplishing this first step requires more than just a passing knowledge of anatomy.

Small (Targeting) Electrode Placement

The relatively small (2 to 3 cm in diameter) targeting electrode should be a small to medium self-adhesive, sponge and/or vasopneumatic device. It should be placed approximately where the practitioner would insert a needle for a chemical nerve block of the same nerve. Accommodations must be made for the visualized pathway of the electric current.

For nerve root blocks, there are two possible electrode placement patterns. One is posterior on the surface cutaneous to the nerve root. The other is contralateral to the target nerve root. The other or large electrode would then be placed as in the next section.

For predominantly C-fiber pathology, the practitioner chooses to place the small electrode superior to the most distal sympathetic ganglion for the lower extremities and inferior to the stellate ganglion (over the T2 sympathetic ganglion) ipsilaterally for upper extremity problems. Placement for thoracic pain is straightforward as long as the practitioner visualizes the path of least impedance combined with the shortest distance; scatter occurs as the electric current crosses tissue planes/interfaces.

Large (Dispersal) Electrode Placement

The relatively large (3 to 5 cm in diameter dispersal) electrode should be a medium to large self-adhesive, sponge and/or vasopneumatic device. It should be placed either across the target nerve or distally along that nerve's distribution. It is better to follow the dermatomal distributions in predominant A-delta fiber neuropathology. For predominantly C-fiber pathology, the practitioner chooses to place the large electrode down the involved extremity, possibly even into a container of water or other ionic fluid in which the distal extremity is immersed. Placement for thoracic pain is straightforward as long as the practitioner visualizes the path of least impedance combined with the shortest distance; scatter occurs as the electric current crosses tissue planes/interfaces.

Each Treatment

The practitioner sets the intensity to tolerance during the first 30 seconds of the treatment. Turning the intensity up during the treatment may result in damage to the insensate (from the nerve block itself) skin. The ideal treatment lasts for 20 minutes and uses a frequency of approximately 15 kHz (anywhere between 4,000 and 40,000 Hz will do). Some machines sweep across frequency ranges, and sweeping theoretically results in recruitment of wider bands of nerve fibers, causing more complete pain control.

Possible Combined Treatment

The physician, depending on the exact character and distribution of the patient's pain, may place a second set of electrodes across the area of "worst pathology." For longitudinally extensive pathology, a second set of the electrodes placed differently to cover the same distribution may be better.

Treatment Course

Daily electromedical sessions for 3 weeks usually result in clinical improvement as long as the underlying peripheral pathology is being treated and corrected at the same time. Logistics and third-party payer resistance seldom allow this intense course of treatment.

It has been found that the first five treatments, if done within a 2-week period, can result in benefits. As stated above, occasional patients seem to worsen, but most do improve. Without some benefit noted, the practitioner should move on to other treatment alternatives, or at least combine ENBs with other therapeutic methods. An average of 10 to 15 treatments, each separated by 3 days or fewer are necessary to achieve optimal or maximal benefit. Longer intervals between treatments usually make more treatments necessary.

Better results are obtained when combined with adjunctive therapy, such as nutritional support, modalities, therapeutic exercise, chiropractic manipulations, chemical injections, or psychological techniques. Frequent reassessment improves outcome because the practitioner can make adjustments in the electromedical or adjunct care. Subjective (pain scores) and functional (ROM, MMT, etc.) assessment should both be done periodically, immediately before and after the ENBs.

Precautions

While avoiding conduction through the carotid sinus is logical and appropriate, risk of cardiovascular adverse events is minimal with ENBs. The cardiac system operates at one cycle per second (normal heart rates are 60 to 100 beats per *minute*), whereas machines used generate alternating currents of at least 4,000 per *second*. Davis (1993) showed that the higher the frequency, the lower the relative risk. On the other hand, as the total electrical energy increases, the likelihood of overriding the natural frequency increases.

Because the total electrical current going through both the small and large electrodes is the same, the impor-

tant variable is the current density (Schwartz, 1998). The so-called targeting electrode can be considered to concentrate electrical energy at the targeted nerve(s). Practitioners should know that the point in the circuit with the greatest current density at the skin surface is where the skin can most possibly be damaged. Using small self-adhesive electrodes, skin burns are possible, but are they rare with sponges.

Contraindications for ENBs

- Pregnancy
- Multiple sclerosis
- Parkinson's disease
- Epilepsy
- Vascular diseases/manifest thrombosis
- Acute inflammatory process
- Bacterial infection (osteomyelitis, etc.)
- Malignancies
- Metal implants
- Arrhythmia/demand pacemaker
- Over the carotid sinus
- Across the cranium

Although these are "official" contraindications according to the FDA, full knowledge and understanding of the basic principles of ENBs may allow usage on some body locations for most of these diagnoses.

ENB MACHINES

Any electric current devices producing AC of 4,000 to 20,000 cycles per second are probably capable of producing ENBs. While some manufacturers claim that square wave machines, machines that are specifically designed for interferential treatments, are more comfortable than sine wave machines, sine wave generators seem to produce more pain relief. Via a different mechanism, high volt galvanic current (HVGC) machines appear to achieve ENBs. Jenkner (1995) based most of his conclusions in *Electric Pain Control* on a rapidly pulsing direct current theoretically similar to HVGC.

PITFALLS: CAUSES FOR FAILURE

Without visible tissue changes and improvement in the pain, there may not be a peripheral pain generator. Blockade of any nerve is more difficult to confirm because the pain pathways can be missed. These pathways may not always follow the anatomic distribution of that nerve.

Trauma of the needle used in chemical nerve blocks and the caustic effects of those chemicals cause scar tissue accumulation. If multiple chemical blocks have preceded ENBs, the resultant scar tissue around the nerve may interfere with penetration of the electric current. This scar tissue is avoided with ENB procedures.

For the best results, the right medical diagnoses are necessary so that the specific pathology can be treated. An incorrect primary diagnosis is possible. This mistake can result in inappropriate electrode placement. If the proper diagnosis is made and results from these techniques are less than expected, the pain could be generated from two or multiple sites. If the pathology is in a different area than the treated tissue, the current density could be too low to promote the nerve block. If the sympathetic nerve damage is more distal, patients may obtain pain relief without changing the nerve pathology. If the pain generator is nearby, but in a different nerve distribution, the treatment may not work well at all and/or the pathology could be too proximal or too distal to the treated area. As it may be difficult for the patient to immobilize the involved tissue, recurrent pain might be expected. As it is not impossible for central pain to occur with changes in the neurons of the dorsal horns, in the spinal pain tracks, and/or in the brain, in subcortical pathways and in the sensory strip, centrally and sympathetically maintained pain can result from anatomic and physiologic changes in central nerve system neurons. Deafferent or central pain responds poorly if at all to peripheral procedures of any type. Finally, pain maintained by psychological mechanism may fail to respond to ENBs alone, further establishing the need for multidisciplinary care.

MEDICAL PLACE OF ENBS: EFFECTS/BENEFITS

These ENB treatments have the potential to "cure" the pain pathology. If a purely neuropathic condition exists, one may expect to "cure" the patient with ENBs. Because "cure" with ENBs has been rare, one must assume that the causative pathology is ongoing in nearly all pain conditions. In other words, it appears the ENB frequencies may reverse the neuropathology, but not the underlying ongoing cause of the neuropathology. Therefore, most practitioners suspect from experience that an individualized multidisciplinary approach is necessary to help patients with ongoing pain (Rosomoff, 2000). ENBs are only one tool that must be combined with other supplemental and synergistic techniques, and those methods must be dynamically changed and refined over the course of the pain disease; once again, there is "no magic bullet."

If kept in perspective, ENB as a medical procedure is a powerful tool for treating the pathology and pain originating from neuropathy, peripheral or central, and afferent distribution. There is also the obvious benefit of completely avoiding the need to pass a needle through other tissue. Single or multiple injections can result in new scar tissue anywhere the injected fluid goes. Thus, ENBs avoid the development of scar tissue in and around nerves that

interferes with the effectiveness of subsequent treatments, electromedical or chemical.

CONCLUSION

ENBs can and should be included in comprehensive treatment programs for temporary pain control and normalization of neuropathic problems. Proper use of ENBs requires an understanding of neurouanatomy, neurophysiology, and the mechanism of ENB action.

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