Advances In Therapy® | Vol. 8, No. 1
January/February 1991

Electric Sympathetic Block: A Review of Electromedical Physics

Robert G. Schwartz, M.D.
Department of Physical Medicine and Rehabilitation
Medical University of South Carolina
Charleston, South Carolina

ABSTRACT

Electric sympathetic block is the procedure whereby blockage of the sympathetic nerve fiber is achieved by applying controlled electrical pulses via electrodes placed on the skin. An electric block of the sympathetic fiber can occur with a direct monophasic current to achieve an anodal block, a middle-frequency Endosan® * current to effect sustained depolarization, or an interferential current to achieve a fatiguing effect. The physics and theoretical framework underlying the currents used in this procedure will be reviewed.

Keywords: electromedicine; pain; sympathetic block

INTRODUCTION

Electric Sympathetic Block

At the cornerstone of basic science in the explanation of electromedical physiology and mechanism of action is the strength duration curve which relates the strength of an electrical pulse to the length of time it must be applied to tissue to produce a response. As a nerve becomes more or less excitable its strength duration curve shifts. This shift demonstrates that the more stable the nerve membrane the greater the stimulus necessary to depolarize it.[1]

The strength duration curve depends on both the characteristics of the affected nerve fiber as well as the electrical impulse being applied. Specific parameters are required for an electrical impulse to be selectively applied to a specific type of nerve fiber. These parameters are dependent on the characteristics of that nerve fiber.[2,3] Variables of the

*Endosan® is a registered trademark of Nemectron Medical Inc., Temecula, CA.

electrical impulse include pulse width, inter-pulse interval, frequency, current (or voltage), and waveform configuration. Other factors that affect the impulse include the size, shape, and placement of electrodes, and impedance.[3,4]

Pulse charge can be defined as the amount of electrical energy delivered to the tissue with each phase of each pulse. When pulse intensity and rate are constant, increased pulse duration will result in increases in pulse charge and average current. Thus, modifying the pulse duration does not change the depth of penetration, but rather affects the recruitment of nerve fibers. Increased pulse duration recruits fibers of smaller diameter. With constant pulse duration and rate, increased intensity is associated with deeper penetration and recruitment of new and deeper nerve fibers.[4]

Anodal Block

If a direct monophasic waveform is utilized instead of a biphasic wave, it is possible to establish an anelectrotonic potential outside the nerve fiber membrane to decrease nerve excitability. The result is an anodal blocking capability of that waveform.[1,5-9]

Current density is affected by electrode size, depth of penetration, and tissue impedance. The smaller the electrode, the greater the density of current concentration at that electrode. Depth of penetration is greater but current density less with larger distances between electrodes. If larger interelectrode distances are utilized, greater tissue impedance is encountered, and a greater potential difference between electrodes will be necessary to achieve an effective current density.[3]

In order to increase the current density under the anode, a smaller, disc-shaped electrode at the anode and a larger, oval-shaped cathode should be utilized. The oval or oblong shape of the cathode causes the field from the anode to fan out in one place rather than in planes of another direction (e.g., perpendicular to it).[9]

In order to affect the sympathetic chain, electrode placement must be such that the concentration of the current is sufficiently strong. This is accomplished by placing electrodes on opposing surfaces of the body with the anode over the sympathetic ganglia.[3,6,9]

The efficacy of nerve blocking depends on the amount of energy delivered to the nerve fiber. A large potential difference is necessary in order for the impulse to cross through large impedances. This can be achieved without the undesirable effect of painful sensation during current flow if the duration of single stimuli is limited to under 200 microsec, thereby providing at least 50 to 100 times the duration of the pulse width during the interval between pulses when a frequency of 35 to 50 Hz is employed.[3,9,10]

The electrical properties of the strength duration curve as well as the physics of waveform morphology and electrical pulse density place restrictions on the pulse parameters that can be employed if an anodal block is desired and is delivered with a nonpainful stimulus. There are further restrictions placed on the pulse parameter if the sympathetic and C fibers are to be selectively affected. The characteristics of these nerve fibers are:

1. No myelination.
2. Slow conduction.
3. High threshold.
4. Longer refractory period.
5. Longer chronaxie values.

From these characteristics and through examination of strength duration curves it has been determined that the sympathetic and unmyelinated, small-diameter C fibers can be selectively recruited by impulses of relatively large amplitude, low frequency, and long duration. Parameter adjustments should include a rate of approximately 35 to 50 Hz, pulse width of 100 to 200 microsec, and amplitudes of up to 30 mA.[1,2,6,7]

In summary, when a direct monophasic waveform with a duration of less than 200 microsec is applied in a frequency range of 35 to 50 Hz with a high mA or voltage (so as to obtain a strong impulse) by electrodes properly placed and of markedly dissimilar size, an electric sympathetic nerve block can be obtained without the undesirable effect of painful sensation during current flow.[1,6-9]

Sustained Depolarization

The undesirable effect of painful sensation can also be avioded by utilizing a middle-frequency Endosan® current to achieve the desired therapeutic effect. In this instance depth of penetration is assured as a result of the lower skin impedance associated with the middle-frequency current, and electrode size and placement. An effective block can occur through sustained depolarization when a continuous refractory state is achieved.[11,12]

Electrically, the skin and tissue layers may be considered capacitors. The impedance of a capacitor increases as the applied frequency decreases. A middle-frequency Endosan® current requires less energy to overcome the outer skin and tissue barriers, thus facilitating the delivery of more current to deeper tissues.[13]

To further ensure depth of penetration, two electrodes are utilized on opposing surfaces of the body, thereby creating a vector of current, or a summation field between them. In accordance with the law of excitation (all or nothing), current density is adequate if an action potential arises. As in the case of the anodal block, a smaller electrode is placed over the sympathetic ganglia affected with a larger electrode on the opposing body surface. This provides the effect of further increasing the current density at the ganglia where the block is desired.

Bipolar alternating currents of frequencies up to 1000 Hz stimulate according to the principle of cathodal closure (anelectrotonic inhibition) and anodal opening (catelectrotonic stimulation). As the frequency of an alternating current becomes high enough to fall within the absolute refractory period of the nerve, it can lead to either occasional cathodal closure tetanus or more commonly to the disappearance of all excitation with a continuous refractory state (Wedensky inhibition).[8,12]

The Fatiguing Effect

When two different middle-frequency currents of approximately 4000 Hz are utilized, there can be a criss-crossing of currents. This is referred to as an interferential current. With interferential currents, there can also be variation in the electrode generating the current and the utilization of slightly different frequencies between intersecting currents. The frequencies of the two currents may differ by as much as 200 cycles. This creates an enveloping of the currents so as to yield a low-frequency effect between 0 and 200 cycles.

With this current type, the higher middle frequency permits lowered skin impedance to the current while at the same time the deeper tissues experience a lower frequency (0 to 200 Hz) range. If the generating electrode of the current is varied, along with a criss-crossing of currents, a vector is obtained so as to ensure current density within the superposition of the fields.[13]

In this instance the middle-frequency current does not exert its effect according to polarity, but according to the apolarity principle. A middle-frequency current of this type effects bipolar excitation of the nerve at both poles of the current at the same time and in the same way. This is called ambipolar stimulation. With interferential current it is not possible to demonstrate Wedensky inhibition, but perhaps the repeated production of stimuli produces a loss of accommodation which results in an eventual fatiguing effect on the nerve fiber.[12]

In summary, with middle-frequency Endosan® currents, sustained depolarization is achieved through Wedensky inhibition to create the effect of a sympathetic block. Depth of penetration is ensured when electrodes of dissimilar size are placed on opposing body surfaces. The smaller electrode is placed over the ganglia to which treatment is directed. While less is known about the effect of an interferential current, a fatiguing effect is postulated.

CONCLUSION

The physics behind electromedicine with direct monophasic, middle-frequency Endosan®, and interferential currents and their use in achieving an electric sympathetic block have been reviewed. While the case for interferential currents is not as conclusive, both the theoretical framework and the literature suggest that when applied with the proper parameters, electrode size, and configuration, both direct monophasic and middle-frequency Endosan® currents can be utilized to achieve an electric sympathetic block.

REFERENCES

1. Goodgold J: "Electrodiagnosis of Neuromuscular Diseases." Williams & Wilkins, Baltimore, 1983.
2. Guyton AC: "Textbook of Medical Physiology." W.B. Saunders Co, Philadelphia, 1986.
3. Mannheimer JS and Lampe GN: "Clinical Transcutaneous Electrical Nerve Stimulation." F.A. Davis Co, Philadelphia, 1984.
4. Alon G: "High Voltage Stimulation." Chattanooga Corp, Chattanooga, 1984.
5. Zohn DA: "Musculoskeletal Pain." Little, Brown and Co, Boston, 1988.
6. Ganong WF: "Review of Medical Physiology." Lang Medical Publications, Los Altos, 1983.
7. Shriber WJ: "A Manual of Electrotherapy." Lea & Febiger, Philadelphia, 1977.
8. Campbell JN: Local analgesia from percutaneous electrical stimulation. *Arch Neurol* 1973; 28:347.
9. Jenkner FL: "Transcutaneous Electric Nerve Block." Springer Verlag, New York, 1986.
10. Downey JA: "Physiological Basis of Rehabilitation Medicine." W.B. Saunders Co, Philadelphia, 1971.
11. Schoeler H: Physical block of the sympathetic chain. *J Technik Med* 1972; 1:16-18.
12. Wyss OA: Middle frequency pulsed stimulation as a principle of interference stimulation with middle frequency sinus currents. *Asklepios* October 1965; 6:10.
13. Hansjurgens A: Dynamic interferential current therapy. *Phys Med Rehab* 1974; 15:24-28.