Transcutaneous Neural Stimulation, Acupuncture and the Current of Injury

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Abstract: Stimulating techniques to produce analgesia have long been known, i.e., massage and in recent years transcutaneous neural stimulation has become very popular. Dry needling by acupuncture may also be considered as another form of "stimulation-produced analgesia." In T.N.S. the source of electrical stimulation is exogenous, while that in acupuncture is endogenous and represented by the current of injury. Stimulation of the peripheral nervous system produces analgesia by neurological and neurohumoral inhibitory effects at the spinal gating mechanism, the ascending inhibitory path and the brainstem anti-nociceptor system. The humoral agent has been recently suggested to be endogenous morphine-like peptides which affect opiate receptors in the brain and at the spinal cord levels. Many painful syndromes which respond to T.N.S. or acupuncture are probably secondary to neuropathy and "denervation supersensitivity." Denervation supersensitivity may be reduced by stimulation in an apparently continuously graded manner with increases in the number of stimuli or stimulus frequency. To be effective, stimulus trains should not be separated by periods of more than a few hours. The current of injury produced by acupuncture, being constant, would therefore seem to have an advantage over intermittently-applied transcutaneous neural stimulation, although the current of injury being small, has to be accurately applied to specific points in muscle.

IN RECENT YEARS the use of transcutaneous neural stimulation or transcutaneous electrical neural stimulation (T.N.S. or T.E.N.S.) to produce an analgesic effect has received universal acceptance.[1-5] By contrast there seems to be a general reluctance of the medical profession to accept acupuncture. This paper postulates that they are, in effect, similar techniques for 'stimulation-produced' analgesia[7-8] with the source of electrical stimulation in transcutaneous neural stimulation exogenous, while that in acupuncture endogenous and represented by the current of injury.

Stimulating techniques to produce analgesia or "stimulation-produced analgesia" have long been in use, e.g., massage or percussion of painful areas, but it was only within recent years that its mechanism has been studied. Stimulation of the peripheral nervous system, either in the form of acupuncture or transcutaneous neural stimulation, may produce analgesia by neurophysiological and neurohumoral inhibitory effects at the spinal gating mechanism, the ascending inhibitory path or the brainstem anti-nociceptor system.

The spinal gating mechanism or the "gate control" theory of Melzack and Wall, first proposed in 1965, was restated this year[9] —

(i) Information about the presence of injury is transmitted to the central nervous system by peripheral nerves. Certain small-diameter fibers (A-delta and C) respond only to injury while others with lower thresholds increase their discharge frequency if the stimulus reaches noxious levels.

(ii) Cells in the spinal cord of fifth nerve nucleus which are excited by these injury

signals are also facilitated or inhibited by other peripheral nerve fibers which carry information about innocuous events.

(iii) Descending control systems originating in the brain modulate the excitability of the cells which transmit information about the injury.

The so-called ascending inhibitory pathway for pain refers to the inhibitory effect by strong stimulation of the peripheral nerve on the response of single neurons of the nuclei parafascicularis and centralis lateralis of the thalamus to painful stimulation of the extremities.[10] It may result from a reduced flow of impulses due to suppression at the spinal level although thalamic cells may be also actively inhibited.

Stimulation of certain areas of the brain also produced definite inhibitory actions on the sensory input and analgesia may be produced by focal stimulation in the central gray matter of the midbrain[11] or the brainstem.[12] This selective lowered responsiveness to noxious stimuli from focal electrical stimulation parallels that of the site and mode of action of morphine.[8, 13, 14, 15] The studies of Hughes, Kosterlitz and others[16, 17, 18, 19] have shown that endogenous morphine-like peptides inhibit neuronal activity by altering sodium conductance at opiate receptors in the brain and at spinal cord levels. These receptors have also been localized to the substantia gelatinosa of the caudal spinal trigeminal nucleus which receives fibers from the face and hands via branches of the trigeminal, facial, glossopharyngeal and vagus nerves (and may explain auricular acupuncture). Effective stimulation at the peripheral nervous system may possibly also generate afferent impulses to stimulate the pituitary gland to produce pituitary opioid peptides.[20, 21] The pituitary gland also possesses opiate receptors, mostly in the posterior pituitary and it is known that opiates enhance the release of antiduretic hormone, FSH and ACTH.[13, 22, 23]

Stimulation in transcutaneous neural stimulation is via intact skin using an exogenous source of current, whereas in acupuncture the current is endogenous, represented by the current of injury. The concept of muscle-generated electricity was first announced by Galvani over a hundred years ago and muscle potentials were recorded in 1826 and the injury current described in 1843.[24, 25] If a suitable galvanometer is connected to two electrodes, one applied to the intact surface of a nerve or muscle and the other to the cut or injured part of the same nerve or muscle, a deflection will result indicating that the injured part is negatively charged in relation to the intact surface. These electrical phenomena are known as demarcation currents or injury potentials. In mammalian muscle, resting cell membrane has a high electrical impedance and a low permeability for ions. It is charged positively on the outside and negatively within, the potential difference being nearly 100 millivolts. This potential difference is maintained by the specific ion concentration difference between the inside of the nerve or muscle cell (high potassium and very low sodium concentration) and the surrounding extracellular fluid (high sodium and low potassium concentration). When excitation occurs, the positive polarization of the outside of the membrane at the zone of excitation is depolarized with a differential change in sodium and potassium permeability. In contrast to an exogenous source of stimulation, the duration of which is determined by the length of application, the current of injury remains in effect possibly for several days until the microtrauma heals. This length of duration of stimulation, as will be seen later, is of practical significance.

Many pain syndromes, particularly those of "musculoskeletal" or "myofascial" types are probably related to neuropathy[26] and "denervation supersensitivity" (Cannon's Law).[27] These diverse pain syndromes of apparently unrelated etiology, e.g., "bursitis," "tennis elbow," "tendinitis" and even "causalgia" may be attributable to abnormal noxious input into the central nervous system from supersensitive receptor organs (nociceptors) and hyperreactive control systems at internuncial pools. These may become supersensitive or hyperreactive following "denervation."[28-30]

For example, changes in muscle following neuropathy or denervation of some axons include an increase in the surface area of the muscle fiber which is sensitive to acetylcholine. Normally the area of receptor sensitivity is very sharply demarcated, but when muscle loses its motor innervation there is a marked increase in the degree to which extrajunctional membrane responds to the application of acetylcholine. This change is detectable within a matter of hours and reaches a maximum in about a week. Together with this, there is an onset of spontaneous electrical activity of fibrillation. This autogenic activity probably arises from local fluctuations in membrane potential and from an increase in membrane permeability to electrolytes. There are also changes in muscle structure and biochemistry and muscle atrophy eventually occurs with a progressive destruction of the fiber's contractile elements. Furthermore, unlike normal muscle fibers which resist innervation from foreign nerves, degenerated muscle fibers accept contacts from other motor nerves, preganglionic autonomic fibers and possibly even sensory nerves.

There are similar changes in neurons. (Cannon's Law indeed states that denervation supersensitivity is a universal phenomenon, affecting muscles, nerves, salivary glands, sudorific glands, autonomic ganglion cells, spinal neurons and even neurons in the cortex). Sensitivity to acetylcholine appears at every point on the cell surface instead of only at the normal synaptic regions. Neurons also develop spontaneous activity analogous to fibrillation and like muscle these neurons become receptive to foreign innervation inducing sprouting of nearby pre-synaptic elements. Nociceptors may become hypersensitive so that their threshold drops and they are excited by normally innocuous stimuli.

Lomo,[31] in animal experiments, has shown that denervation supersensitivity in muscle may be reduced or abolished by electrical stimulation. Hypersensitivity as assayed by the sensitivity of muscle extrajunctional membrane to acetylcholine diminishes at a rate which depends critically on the amount and pattern of the stimuli. The rate of decline of acetylcholine hypersensitivity is enhanced in an apparently continuously graded manner with increases in the number of stimuli, or if the number of stimuli is kept constant, with the stimulus frequency within the trains (Fig. 1). High frequency stimulation was found to be more effective, e.g., 100 Hz was found to be ten times more effective than 10 Hz. High frequency stimulation was also more effective in delaying the reappearance of hypersensitivity when stimulation was stopped. Even very low levels of stimulation strongly suppress hypersensitivity; as few as a hundred stimuli (10 Hz for 10 seconds) given approximately every five hours for three weeks was shown to cause a ten-fold reduction in acetylcholine sensitivity. However, frequency stimulus trains separated by long periods, e.g., repeated every 24 hours had much less effect than when given throughout the 24 hrs. In this respect, the current of injury, being constant, would appear to have the advantage over intermittently-applied transcutaneous neural stimulation, but the current of injury, being smaller, has to be induced accurately in the muscle motor band of innervation. In a recent randomized clinical trial with long-term follow-up, using dry needling acupuncture on motor points for chronic low back pain, it was found that treatment was necessary only once or twice a week and that supplementary electrical stimulation via the needle was not superior to dry needling alone.[32] Treatment points in this study were chosen on a neurophysiological basis and in accordance with the segmental level of injury instead of the traditional and empirical method of Yin and Yang, although a comparison of points thus treated with those of traditional acupuncture revealed a remarkable similarity in distribution. Results in the acupuncture group were found to be statistically better than in the control group ($P > 0.005$, $N = 53$).

Discussion

The reluctance to accept acupuncture by the medical profession in general is due to many factors, not the least is the innate skepticism present in all of us. It has been said that, "In

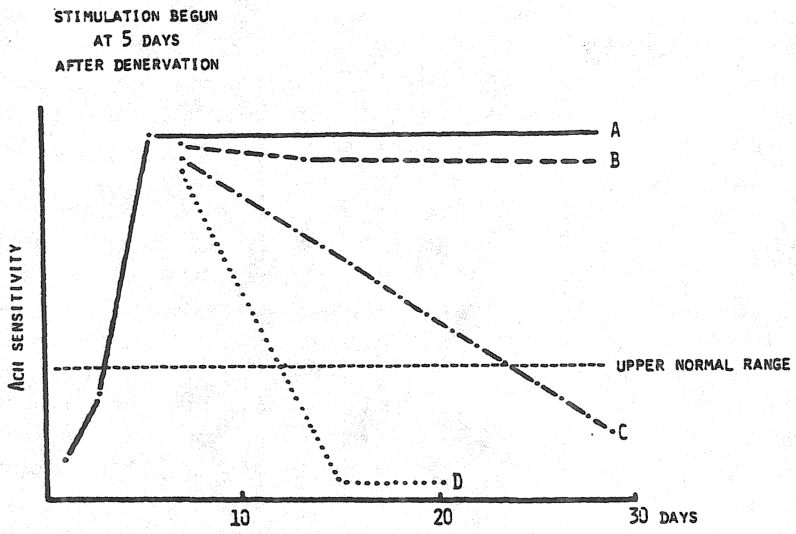

Fig. 1.

In animal experiments, T. Lomo has shown that direct muscle stimulation causes denervation hypersensitivity to ACH to decline at a rate dependent on the number of stimuli. Identical trains of stimuli 10 Hz for 10 seconds given at:

A — Untreated.
B — 14-hourly intervals.
C — Approximately 3-hourly intervals.
D — Continuously.

medicine, objections against new developments are generally only the spontaneous reaction of the individual's inborn dogmatism against that which tends to force on him a different conception of the facts from the one he was used to." Perhaps today, in view of the accumulating scientific evidence for acupuncture, those who are resistant should reconsider their stand.

It is not a simple task to explain the oriental art of acupuncture, based on ancient philosophy, into modern scientific terms, but there have been attempts to translate some of the traditional concepts of meridians, the esoteric appelation of acupuncture points into modern scientific terms with a neurophysiological basis.[33-36] Present available evidence indicates that the development of analgesia depends upon the stimulation of specific points in muscle corresponding to certain types of muscle receptor.[37] Most acupuncture points, it is now accepted, correspond to muscle motor bands of innervation or motor points.[33, 38] The transmission of a painful stimulus, it is now known, may be blocked by other afferent inputs at the spinal and thalamic levels with descending inhibitory influences from the raphe nuclei which are activated by the muscle afferents. Some of the humoral agents involved have now been shown to correspond to endogenous opioid peptides and ACTH.

To allay suspicion and overcome prejudice, as well as to improve acupuncture techniques, we have previously proposed that the traditional nomenclature be replaced or augmented with one using neuroanatomic terms. Transcutaneous neural stimulation has its limitations in that the source of stimulation is exogenous, its duration limited to the length of application and the current has to penetrate cutaneous tissues which are rich in small-diameter pain-sensitive nerve endings to reach the zone of innervation which is deep in muscle; while dry needling when accurately placed produces a current of injury which lasts possibly for several days. On the other hand, the use of a needle requires a knowledge of anatomy to prevent penetration of vital organs and strict adherence to aseptic techniques to prevent infection.

Although the comments in this paper are concerned primarily with the pain-relieving effects of acupuncture, its use as a therapeutic agent for various ailments may also have a scientific basis related to the release of ACTH and the anti-stress properties of the autonomic nervous system. These will be dealt with in a subsequent paper.

Summary

Transcutaneous neural stimulation has been used almost universally in recent years with dramatic pain-relieving effects. In contrast to its remarkable success and acceptance, acupuncture is still meeting with skepticism within the medical profession. In effect, these are probably similar techniques for producing "stimulation-producing analgesia." In the case of transcutaneous neural stimulation, the source of current is exogenous, whereas that in acupuncture is endogenous and represented by the current of injury.

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