Is Pulsed Radiofrequency a Neuromodulation Technique?

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In this issue of Neuromodulation, J. Van Zundert et al. have published an article titled, Percutaneous pulsed radiofrequency treatment of the cervical dorsal root ganglion in the treatment of chronic cervical pain syndromes: A clinical audit (1). The question that our readers might ask is this: Is pulsed radiofrequency neuromodulation? It is the opinion of these authors that it is.

The exact definition of neuromodulation is hard to find in the literature. Neuromodulation is considered a normal property of the nervous system that regulates or modifies electrical impulses flowing through neural tissues by enhancing, inhibiting, extending, or shortening them. Interventional neuromodulation is considered nondestructive and reversible therapy and includes the use of implanted or nonimplanted electrical stimulation systems, electrically stimulating peripheral nerves, dorsal root ganglia, the spinal cord, or the brain, and chemical neuromodulation, the infusion of chemical agents directly to the central nervous system. Considering that the accepted definition of therapeutic neuromodulation only includes either electrical stimulation of the nervous system or chemical modulation of the nervous system, could we consider the new technique of pulsed radiofrequency of cranial nerves, dorsal root ganglia and peripheral nerves as neuromodulation?

Neuromodulation of nociceptive information takes place in spinal synapses through presynaptic and postsynaptic inhibition. The gate control theory described by Patrick Wall and Ronald Melzack in 1965 postulates that reception and activation of small fiber, nociceptive, afferent information, at the spinal, gray-matter level, is inhibited by activation of large, A-beta afferent fibers, preventing the release of substance P presynaptically (2). Descending inhibitory control is also another example of neuromodulation. There exists a series of descending pathways starting in upper neural centers and terminating in the spinal cord. These upper neural centers, including the nucleus raphe magnus, the paragigantosuperior reticulum, the peri-aquadectal gray, and the substantia nigra can all be activated by direct spinal electrical stimulation or intrathecal chemical neuromodulation, inhibiting the sensation of pain along the descending pathways. As previously stated, therapeutic electrical stimulation of the nervous system includes peripheral stimulation of the nervous system (transcutaneous nerve stimulation (TENS) (3), and peripheral nerve stimulation (PNS) (4)), spinal cord stimulation (5), and stimulation of deep brain structures and motor cortex (6).

Spinal cord stimulation (SCS) acts upon any structure or tract of the spinal cord if the electrical...
The posterior or dorsal columns, the dorsal gray matter, the dorsal root ganglia, the pyramidal tracts, the spinoreticular tracts, the ventral nerves, and the sympathetic chains may all be activated by stimulation of the spinal cord, depending on proximity of stimulation or amplitude of stimulation (7). The neurons of the dorsal gray matter do process painful and noxious information, whether somatic or visceral, and their stimulation is thought to cause the relief or suppression of pain.

Administered directly to the spine, by way of intrathecal or epidural administration, opioids and other analgesic substances may exert their spinal effects modulating nociceptive information. These agents either act directly on the primary nociceptive afferent fibers or on second-order neurons (8), or they inhibit neurons modulating nociceptive information, particularly at the substantia gelatinosa, reducing the excitability of the neurons that lead to nociceptive sensitivity of second-order neurons (9).

Radiofrequency thermocoagulation (RFTC) was first used as a neuroablative technique to destroy neural tissues. Examples of RFTC clinical usage include percutaneous cordotomy for oncologic pain (10) and facet rhyzotomy for dorsal or spinal facet syndromes in which the medial branch of the dorsal spinal root is destroyed (11). RFTC is also used in the treatment of trigeminal neuralgias by way of thermal lesioning of one of the branches of the trigeminal ganglion (gasserian ganglion) (12). The very first paper on RFTC of the dorsal root ganglion was published in 1977 (13). Very large diameter insulated needles were used in creating thermal lesions using temperatures of up to and exceeding 75°C. These damaging thermal lesions resulted in both neuroablation and deafferentation.

During the 1990s, other articles began to appear regarding the use of RFTC for cervical (14) and thoracic (15) radicular syndromes. The use of pulsed radiofrequency (production of an electrical field around the tip of insulated needles that do not result in thermal lesions of neural tissues) was motivated by the search for radiofrequency methods that would be selective for the treatment of the C-fibers, leaving large, myelin-containing fibers intact, preventing deafferentation syndromes. What was needed in the minds of early pioneers of this therapy was a radiofrequency technique that worked without generating temperatures that destroyed neural tissues (16). Pulsed radiofrequency is a technique that allows pain-relieving temperatures to be reached with intervals or pauses so that the heat produced can be eliminated by thermal conductance. Mild lesions, by this method, are created without permanent injury to the nerve. Pulsed radiofrequency therefore is not a neuroablative process, but might be considered a neuromodulation process, modulating C-fiber information. The literature contains no reports of sensory or motor injuries after pulsed radiofrequency (14–16).

The mechanism of action of pulsed radiofrequency is not different from conventional radiofrequency therapy. Radiofrequency is applied through an insulated needle that is only activated at the tip of the needle, producing both heat and an electric field at the tip. The degree of heat created at the tip is directly proportional to the intensity of the current passing through the needle tip. The electric field is the movement of the electrons within the tissues when they are exposed to the needle tip's charge. One of the important aspects known about radiofrequency is that there is a known temperature range creating a reversible lesion. A lesion produced between 42 and 44°C is reversible, whereas lesions created by temperatures above 45°C produce irreversible injury.

It is the opinion of these authors that pulsed radiofrequency should be considered a neuromodulation technique. Pulsed radiofrequency is thought to produce its effect only on C-fibers, leaving myelinated fibers intact. It is the purpose of pulsed radiofrequency to produce analgesia without producing destruction of nerves or deafferentation.

It is thought that the use of this technique, at the neurobiological level, results in the expression of the c-fos gene in lamina I and II of the dorsal horn (17). The formation of this gene implies that this electrical field is transmitted to the central nervous system resulting in modulation of nociceptive information. It also implies that its effect is entirely on nonmyelinated fibers. It seems that the expression of this gene leads to the formation of the second RNA messenger, preprodinorphin, which in turn increases the production of endorphins to modulate the analgesic action (18). Furthermore,
the expression of this gene seems to act on the inhibitory and excitatory neurons in the dorsal horn of the medulla (19).

We believe that pulsed radiofrequency is a new form of neuromodulation therapy that is effective for the treatment of radicular syndromes and other conditions that are accompanied by neuropathic pain. The end result of pulsed radiofrequency is analgesia without the development of a destructive lesion. It is also a safe technique, provided that the clinician follows important and relevant technical considerations so as not to produce a heat lesion above 45°C. At present, pulsed radiofrequency appears to be a safe technique with few efficacy studies in the literature. We believe that it is neuromodulation and not neuroablation. Further trials are still needed to identify the true mechanism or mechanisms of action of this technique and its clinical potential in the relief of neuropathic pain syndromes.

REFERENCES


