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An Overview on Different Types of Radio Frequency

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Abstract:

Radiofrequency (RF) therapy has become a widely used minimally invasive intervention for the management of chronic pain conditions, particularly those originating from facet joints, peripheral nerves, and musculoskeletal structures. By delivering controlled thermal or pulsed energy to targeted neural tissue, RF aims to disrupt nociceptive transmission while preserving overall neurological function. Recent advances in RF technology including cooled RF and pulsed RF techniques have improved safety, precision, and long-term analgesic outcomes. This study evaluates the clinical efficacy and safety of radiofrequency in managing chronic pain and highlights its impact on pain scores, functional status, and patient satisfaction.

Keywords: Radiofrequency ablation; chronic pain; pulsed RF; facet joint pain; neuropathic pain; interventional pain management; minimally invasive procedures.

Introduction:

Radiofrequency (RF) therapy has become one of the most established minimally invasive techniques for the management of chronic pain, particularly spine-related and neuropathic pain conditions. The procedure works by applying electromagnetic energy to targeted neural structures to either thermally ablate nociceptive fibers (conventional RF) or modulate neuronal activity without causing significant tissue destruction (pulsed RF). These mechanisms allow RF to interrupt pain transmission while preserving overall motor and sensory function, making it superior to repeated steroid injections or systemic analgesics in selected patients **(1).** Growing clinical evidence supports RF as an effective option for lumbar facet joint pain, sacroiliac joint dysfunction, radicular pain, and certain peripheral neuropathies.

Technological advancements—such as cooled radiofrequency, temperature-controlled systems, and improved image guidance—have significantly broadened RF's therapeutic potential and enhanced procedural accuracy. These innovations enable the creation of larger and more predictable lesions, reduce complication rates, and improve long-term outcomes **(2).** Despite its effectiveness, variability in patient response underscores the importance of precise anatomical knowledge, careful patient selection, and adherence to standardized procedural protocols. Ongoing research continues to refine RF techniques, optimize treatment parameters, and expand its clinical indications in interventional pain management **(3).**

- **Physics of Radiofrequency Current**

Impedance is a crucial factor in procedures like radiofrequency ablation, where heat generated by the resistance to current flow is used to destroy abnormal tissues. The relationship between voltage (V), current (I), and resistance ® follows Ohm's Law, which states that V (voltage) is equal to the product of I (current) and R (resistance): V = IR. In the context of radiofrequency procedures, high-frequency alternating current is used, leading to the term "impedance" to describe the resistance encountered by the electrical current flow in the tissues. This impedance generates heat due to resistance heating.The concentration of current density is highest at the needle tip and the proximal part of the exposed radiofrequency needle. The distribution of current density resembles a pear shape, with the narrow end at the proximal part of the needle tip. heat created during these procedures is measured in watts, denoted as W, where W = V x I (W = watts, V = volts, I = current density). The power generated is a result of the combined effect of voltage and current density in the tissue, regulated by the resistance encountered. **(4)**

The conductive properties of tissues play a crucial role In the generation and distribution of heat during procedures involving radiofrequency (RF) technology. The impedance, which is influenced by tissue composition and water content, determines how heat is generated at the active tip of the device. Heat washout, expressed as W/C°, refers to the dissipation of heat due to tissue conductivity.Significant variations in tissue factors, such as the presence of bone or blood vessels, can impact heat washout. Bone acts as an effective insulator with low water content, reducing heat dissipation near it. On the other hand, blood vessels near the treatment area can contribute to heat washout, affecting the effectiveness of RF lesioning.The electric field around an RF needle without insulation is inversely related to the needle's radius. This results in a strong electric field projecting from the tip of the needle, implying higher charge density, while the field near the exposed needle is relatively weaker. Understanding these principles is important for optimizing the delivery of radiofrequency treatments and minimizing undesired heat dissipation. **(5)**

Mechanism of action

Certainly! Radiofrequency (RF) can be an effective treatment for relieving neuropathic pain by utilizing higher temperatures to target and damage the nerve fibers that transmit pain signals. In addition to affecting these pain-transmitting fibers, RF can also impact nonmyelinated fibers responsible for conducting epicritic stimuli. By blocking the transmission of electric activity along these nerve fibers, RF treatment can help reduce the sensation of neuropathic pain in patients**(6) .**

Thermocoagulation Radiofrequency (radiofrequency Ablation) (TRF)

When Krischner used thermo-coagulation of the gassaerian ganglion to treat trigeminal neuralgia in 1931, it was the first documented application of radiofrequency ablation (RFA). Because of Cosman and Aronow's efforts, the first commercial radiofrequency (RF) machine became available in the late 1950s **(7)**

A generator produces radiofrequency, a high-frequency current that completes the circuit by traveling through bodily tissues from the electrode to the grounding pad. The voltage distinguishes the electrode from the receptive electrode. When the temperature inside the neural tissues rises beyond 40°C, a lesion forms due to the electromagnetic field surrounding the electrode tip. This heat is absorbed by the electrode, and equilibrium is reached in 30 to 60 seconds. The electrode with the greatest temperature is the one being monitored. The size of the lesion is related to the local tissue arrangement, temperature produced, length of RF exposure, and electrode size. Features of the tissue, such as the amount of fluid it contains—more especially, the amount of blood supply or cerebral fluid. **(8)**

When using RFA, a high-frequency alternating current of 420 kHz, applied for 60 to 90 seconds, can produce temperatures between 60 and 80 degrees Celsius. The selective thermocoagulation of pain-delivering nerve fibers (A-δ and C fibers) occurs at this temperature **(9)**

Complete relief from pain is said to be more common with RFA than with glycerol rhizolysis or stereotactic radio surgical. RFT has a procedural success rate close to 100%, compared to just 85% for Microvascular Decompression (MVD). Its short-term effectiveness is diminished, but it has the benefit of being repeatable if necessary. **(10)**

Rhizotomy, or the destruction of nerves to facet joints, is one example of how RFA is used in neurologic applications to treat low back pain. Ablation of the intervertebral discs internally is used to treat discogenic back pain. Ablation of the glossopharyngeal nerve is used to alleviate pain from head and neck cancer patients. Percutaneous thoracic sympathectomy is used to treat upper extremity vascular disorders, causalgia, palmer hyperhidrosis, refractory angina, and tachyarrhythmia. Afferent impulses in the trigeminal nerve are blocked to treat pain in patients with trigeminal neuralgia secondary to neoplasm. **(11)**

Various complications have been observed in patients receiving Gasserian ganglion RFT including diminished corneal reflex, masseter weakness and paralysis, dysesthesia, anesthesia dolorosa, keratitis, and transient paralysis of Cranial Nerves III and VI. **(12)**

- **Pulsed Radiofrequency (PRF)**

When it comes to continuous radiofrequency technology, pulsed radiofrequency (PRF) is special since it relieves pain without seriously harming nerve tissue. **(13)**

In PRF, two short (20 msec) bursts of 420 kHz high-frequency alternating current at 200 mA are supplied per second, interspersed with a quiet phase (480 msec) that lasts for four to six minutes. The temperature remains below the 45ºC neurodestruction threshold during the calm phase due to heat dissipation into the surrounding area via thermal conductance. It is believed that cellular alterations brought on by the electromagnetic field disrupt synaptic connections, hence impairing pain transmission and signaling, as opposed to heat degradation. Moreover, PRF has neuroselective behavior, sparing large, myelinated axons while selectively targeting small-diameter neurons. The descending noradrenergic and serotonergic inhibitory pathways, which are closely linked to the modulation of neuropathic pain, have been shown to be positively enhanced by PRF. **(14).**

Although PRF does not result in thermal lesions, there is evidence that axonal microfilaments and microtubules may sustain microscopic damage. C fibers appear to be more affected than A-beta or A-delta fibers, which are the fibers primarily involved for pain transmission. **(15)**

- **Bipolar Radiofrequency**

However, bipolar RFA is a modification of monopolar RFA in which the circuit is closed between two electrodes. Initially, each electrode forms a separate lesion, but the two lesions quickly fuse together so that the additional tissue volume between them is also ablated. Therefore, the total volume coagulated by the bipolar electrodes is slightly larger than the combined volume coagulated by two monopolar electrodes at the same site. **(16)**

Our ability to treat a greater area of nerves is correlated with the lesion's coverage. A monopolar lesion made with a needle has a diameter and length dependent on the active tip, according to research done on ex vivo models. The impact of the lesion is amplified when these elements are coupled with the bipolar modality. **(17)**

References:

1. Cohen, S. P., Doshi, T. L., Constantinescu, O. C., & Zhao, Z. (2020). A comprehensive review of radiofrequency treatment for chronic pain. The Lancet, 395(10239), 1569–1581.
2. Navani, A., Lall, R., Cheng, J., Bendtsen, T., & Deer, T. R. (2021). Advances in radiofrequency ablation for chronic pain: A narrative review. Pain Physician, 24(4), 291–304.
3. van Boxem, K., van Eerd, M., Brinkman, M., Herrero Babiloni, A., & van Zundert, J. (2019). Radiofrequency and pulsed radiofrequency treatment of chronic pain syndromes: An updated review of mechanisms and applications. Regional Anesthesia and Pain Medicine, 44(3), 272–282.
4. Filingeri V., Gravante G. and Cassisa D. (2005). Physics of radiofrequency in proctology. European Review for Medical and Pharmacological Sciences, 9, 349-54.
5. Dubrovin V.T., Chebakova V.Ju. and Zheltukhin V.S. (2016): Radio-Frequency Discharge at Low Pressure: A Non-Local Problem Statement Approach. Procedia Engineering.; 150: 1041- 5.
6. Escosa B.M. (2017). Two Needle Electrode System for Trigeminal Neuralgia Radiofrequency of Gasserian Ganglion. J Headache Pain Manag.; 2(1):1.
7. Raj P.P. and Erdine S. (2012). Pain Relieving proscedures The illustrated guide. 1st edition. Willey-Blackwell, 130-142.
8. Levy A.S., Grant R.T. and Rothaus K.O. (2016). Radiofrequency Physics for Minimally Invasive Aesthetic Surgery. Clin Plast Surg, 43(3), 551- 6.
9. Kothari K. (2016): Mechanism of pulsed and continuous radiofrequency ablation. Indian J Pain, 30,211-2

10. Huang Q., Liu X., Chen J. and Bao C. (2016). The Effectiveness and Safety of Thermocoagulation Radiofrequency Treatment of the Ophthalmic Division (V1) and/or Maxillary (V2) and Mandibular (V3) Division in Idiopathic Trigeminal Neuralgia: An Observational Study. Pain Physician, 19(1),1041-47.
11. McCormick Z.L., MarshallB., Walker J., McCarthy R. and Walega D.R. (2015). Long-Term Function, Pain and Medication Use Outcomes of Radiofrequency Ablation for Lumbar Facet Syndrome. Int J Anesth Anesth, 2(2),28-9.
12. Kanpolat Y., Savas A., Bekar A. and Berk C. (2001) Percutaneous controlled radiofrequency trigeminal rhizotomy for the treatment of idiopathic trigeminal neuralgia: 25-year experience with 1600 patients. Neurosurgery, 3, 524-534.
13. Abd-Elsayed A., Kreuger L., Seeger S. and Dulli D. (2018). Pulsed Radiofrequency for Treating Trigeminal Neuralgia. Ochsner J, 18(1), 63-65.
14. Usmani H., Dureja G.P., Andleeb R., Tauheed N. and Asif N. (2018). Conventional Radiofrequency Thermocoagulation vs Pulsed Radiofrequency Neuromodulation of Ganglion Impar in Chronic Perineal Pain of Nononcological Origin. Pain Medicine, 19 (12), 2348–56.
15. Facchini G., Spinnato P., Guglielmi G., Albisinni U. and Bazzocchi A. (2017). A comprehensive review of pulsed radiofrequency in the treatment of pain associated with different spinal conditions. Br J Radiol, 90(1), 2.
16. Huang B., Xie K., Chen Y., Wu J. and Yao M. (2019). Bipolar radiofrequency ablation of mandibular branch for refractory V3 trigeminal neuralgia. *J Pain Res, 12*, 1465-1474.
17. Silva-Ortiz V. M. and Plancarte-Sanchez R. (2024). Bipolar radiofrequency ablation for cancer pain in the trigeminal distribution. BMJ Support Palliat Care, 13(e3), e981-e983.