Radiofrequency techniques in pain management

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Learning objectives

After reading this article, you should be able to:

- recognize the principles of radiofrequency in pain management
- describe the different types of radiofrequency employed in clinical practice
- discuss the ways to improve the lesion generated by radiofrequency techniques

Abstract

Radiofrequency techniques are commonly used in management of persistent pain. It involves application of high-frequency alternating current to the neuronal pathways. It is employed for both neuromodulation and neuroablative type procedures in interventional pain management. Technological advances have widened the scope of their use within clinical practice. The evidence base for both conventional and new technologies is accumulating. A clear understanding of the principles and technologies will enable the clinician to use it safely and effectively.

Keywords Bipolar RF; cooled RF; interventional pain management; pulsed RF; radiofrequency

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Radiofrequency (RF) is electromagnetic energy in the radio wave band, which ranges from the sonic band (9–20 kHz) to microwave frequencies (100 MHz–100 GHz). Low-energy, high-frequency alternating current in the range of 100–500 kHz is used in pain management. A specialized RF generator is used to deliver RF energy. It is usually delivered via an insulated needle with exposed tip to the desired target. A ground plate with a large surface area is placed at a location remote from the electrode. The patient completes the circuit while the generator delivers RF energy between needle tip and ground plate (Figure 1). It creates an electromagnetic field at the exposed tip.

Thermal RF

Normally RF is used to create lesions on neuronal target. The passage of RF energy causes oscillation of ions in the conducting tissues. This oscillation releases heat energy, which heats charged molecules, notably proteins causing coagulation, thereby creating a lesion. It is important to note that the needle does not heat up. It absorbs heat generated within the tissue. Thermocouples at the needle tip measure the tissue temperature. Assuming homogeneous conductive medium, heat isotherms are formed around the exposed needle tip (Figure 2) secondary to electrical field. Tissue temperature (T) is directly related to current density (I), but inversely to the fourth power of the radius (R) from the electrode ($T = IR^{-4}$). Current density is less at the distal tip of the needle than its exposed shaft. So the lesion extends radially around the circumference of the exposed shaft. This is in sharp contrast to traditional electrocautery, which causes tissue desiccation by use of high power RF energy. Cautery requires the presence of non-conductive gap between the electrode and target. In essence, it creates a spark in the gap causing tissue desiccation. The depth of tissue damage approaches 4 mm normally and there is no control over the size of the lesion.

The size of the lesion created by RF energy can be modified. The physical variables that determine lesion size are current density, its rate of application, tissue temperature, electrode size, duration of heating, and impedance. Temperature is the fundamental lesioning parameter and temperature monitoring remains central to the safety of the procedure and quantification of lesion size. Since there is no consistent relation between temperature and voltage, temperature-controlled RF lesioning is preferred to create reproducible and well-defined lesion sizes. Sustained conduction block as well as tissue damage is noted at temperature above 45°C. Effective axonotemeis and neurontoemesis ensue at thermal lesions above 65°C. Research shows indiscriminate destruction of large and small fibres to RF thermal lesions rather that selective nociceptive destruction.

If the surface temperature of the electrode increases to 80–85°C, then tissues within a short distance will be heated to 60–65°C. If the tissue temperature increases to 100°C, cavitation (e.g. boiling) will occur and a conductive medium will no longer surround the electrode, thus causing an inconsistent lesion. Hence temperatures between 60 and 90°C are used to achieve consistent lesion.

Lesion size increases with time as the temperature is maintained. Most of the increase in size occurs within 60 seconds, but continues to grow between 60 and 90 seconds. After 90 seconds further growth is prevented because coagulated tissues present an increasing impedance to flow of current.

The size of the lesion is directly proportional to the diameter of the electrode. Experimentally, it is shown that diameter of the lesion is approximately 5 times the width of the electrode. Thus larger gauge needles cause bigger lesions. Since lesions spread radially along the length of the exposed tip, a 10-mm exposed tip creates a larger lesion than 5-mm exposed tip needles. Moreover, they must be placed close and parallel to the target nerve for coagulation of adequate length of nerve. If the electrode is placed perpendicular to the nerve, the lesion may not incorporate adequate length of nerve or even the nerve.

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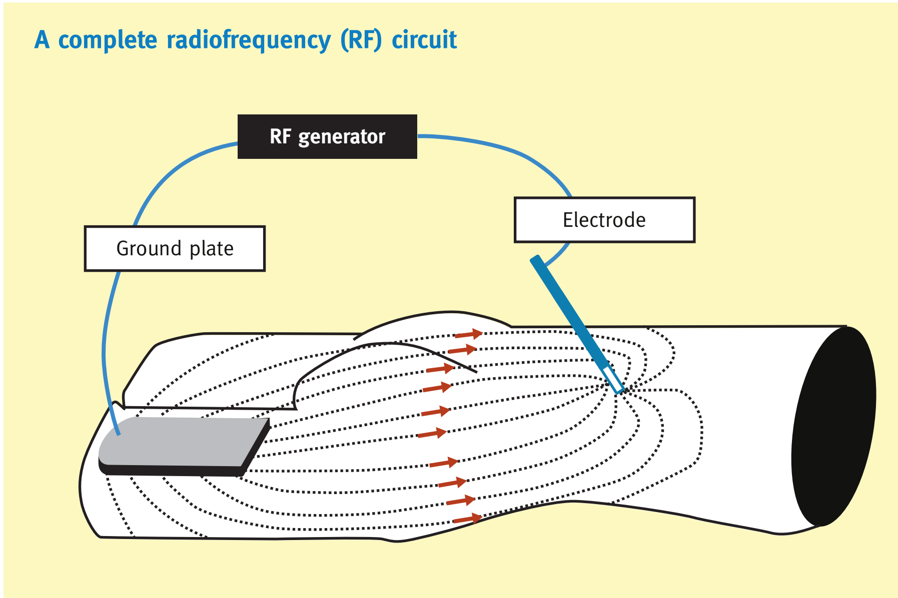

Figure 1

Cooled RF

Cooled RF is a way of increasing the size of the generated lesion. As temperature in tissues in the vicinity of the needle increases, the spread of heat isotherms becomes limited due to increased impedance. Cooled RF technology overcomes the same by internally cooling the needles.

The cooled needle tip acts as a heat sink that removes heat from surrounding tissue, thereby providing adequate conditions to increase the size of the lesion. Thus, time, duration or power deposition can be increased during the procedure without causing high impedance and tissue charring around the needle. So the temperature will be higher away from the tip (Figure 3). The circulation of coolant also affects the shape of the lesion. Distally projecting spherically shaped lesions are created using cooled RF technology rather than elliptical shaped lesions. Thus, cooled RF can be used for creation of larger lesions to ensure that neuronal target can be adequately coagulated.

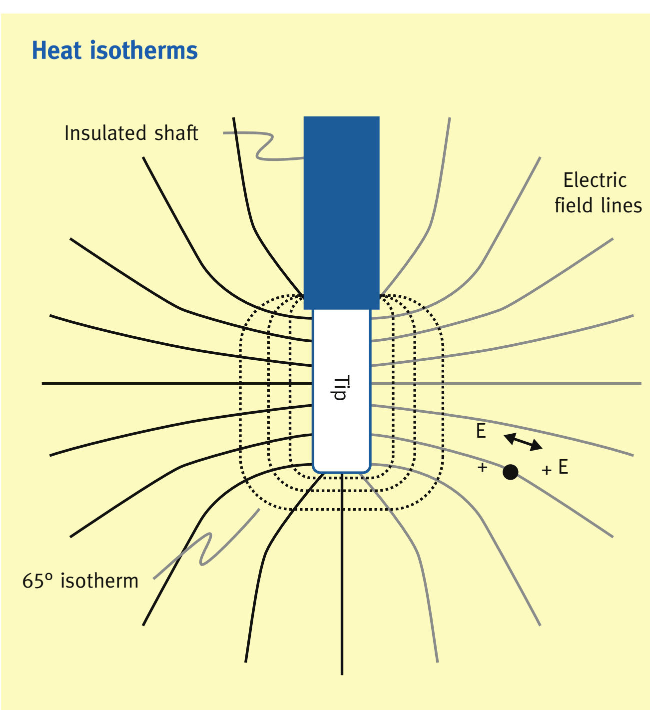

Figure 2

Bipolar RF

Bipolar RF is another way of creating a larger lesion. While a larger dispersive pad, placed away from the target structure in monopolar RF completes the circuitry, it is completed by another electrode placed closer to the intended target in bipolar RF. When the distance between these two electrode tips is brought closer, the shape of the generated lesion transitions from that of a single lesion around each electrode tips to one large strip lesion between the two electrodes (Figure 4). Experimental studies have demonstrated creation of a large strip lesion between electrodes tips spaced as far apart as 12 mm.

Pulsed RF

While thermal RF uses a constant output of high-frequency electric current to produce neuroablative thermocoagulation, pulsed RF utilizes brief pulses of high voltage, RF range (300 kHz) electric current to produce voltage fluctuations and long pauses in between the bursts to dissipate any heat generated (Figure 5). In clinical practice, a 50 kHz current is delivered in 20 ms bursts at a frequency of 2 Hz. The long pauses (480 ms) between the bursts allow heat dissipation. Advances in technology allow us to limit the electrode tip temperature to 42°C. The mechanism of action of pulsed RF is poorly understood and it is debated whether pulsed RF is tissue damaging or not.

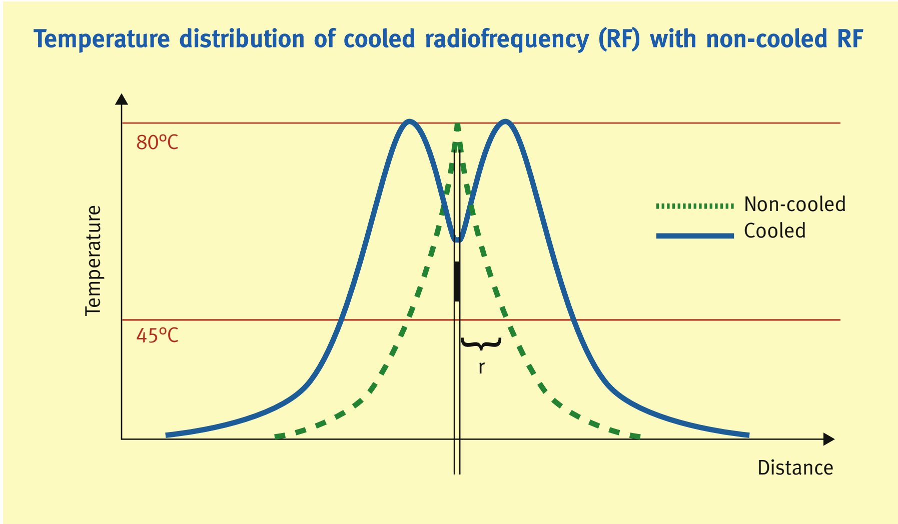

Figure 3

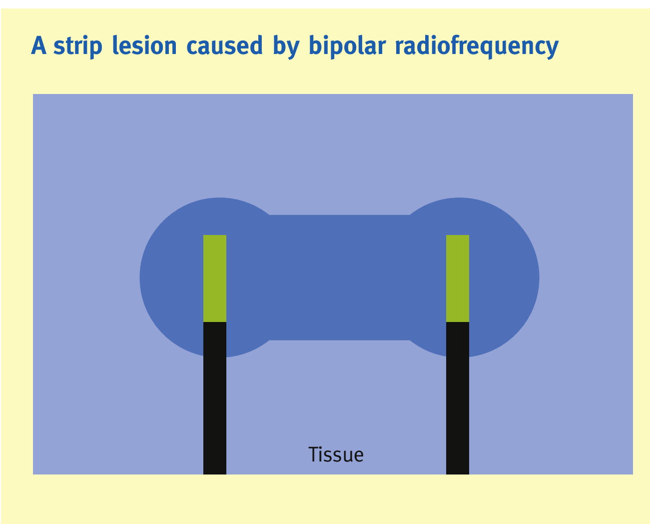

Figure 4

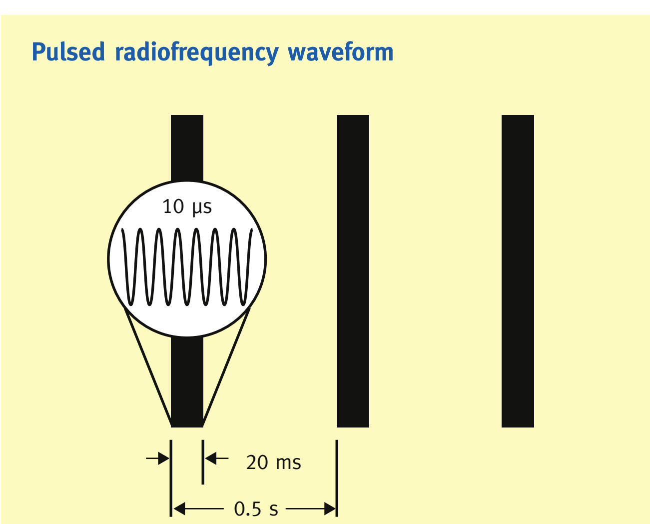

Figure 5

Clinical applications

Thermal RF has the most utility in the treatment of spinal pain. Nociceptive pain arising from facet joints responds well to thermal RF of their nerve supply. The nerve supply of these facet joints has been well defined. The consistent course of the nerves at lumbar level render themselves easily accessible to standard thermal RF. However, the course is considerably variable at both cervical and thoracic levels, thereby necessitating the need for larger lesions. Both bipolar and multiple thermal lesions are employed at cervical level. Cooled RF technology is utilized primarily in the treatment of thoracic facet and sacro-iliac joint pain. Thermal RF is also utilized in other procedures such as percutaneous cervical cordotomy and Gasserian ganglion ablation.

Pulsed RF technology has been used in the place of thermal RF for the treatment of nociceptive pain. However, the evidence base and the duration of pain relief obtained are less compared to thermal RF. In addition, it is employed in the treatment of neuropathic pain conditions such as peripheral nerve entrapment, post-surgical neuropathic pain and radicular pain.

Conclusion

Radiofrequency techniques offer a valid treatment option in the interventional pain management. A clear understanding of the different techniques improves safe and effective use of this technology. ◆

FURTHER READING

Bogduk N, Dreyfuss P, Govind JA. Narrative review of lumbar medial branch neurotomy for the treatment of back pain. *Pain Med* 2009; **10:** 1035–45.

Dreyfuss P, Halbrook B, Pauza K, Joshi A, McLarty J, Bogduk N. Efficacy and validity of radiofrequency neurotomy for chronic lumbar zygapophysial joint pain. *Spine* 2000; **25:** 1270–7.

Lau P, Mercer S, Govind J, Bogduk N. The surgical anatomy of lumbar medial branch neurotomy. *Pain Med* 2004; **5:** 289–98.

