Radiofrequency techniques in pain management

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Abstract

Radiofrequency techniques are minimally invasive procedures used to provide prolonged pain relief compared to local anaesthetic blocks and forms part of a multidisciplinary approach in managing chronic pain. A generator produces a high-frequency current that passes from an electrode to an earthing plate. The electromagnetic field created around the tip of the electrode then has an effect on the surrounding nervous tissue resulting in pain relief.

Keywords Chronic pain; pulsed radiofrequency; radiofrequency thermoablation

Royal College of Anaesthetists CPD matrix: 2E03, 3E00

Learning objectives

After reading this article, you should:

- understand the principles of radiofrequency techniques in pain management
- know the advantages and disadvantages of various types of radiofrequency techniques

Introduction

Radiofrequency (RF) is an electromagnetic radiowave with a frequency ranging from the sonic (9–20 Hz) to microwave (100 MHz–100 GHz). A generator is required to create the RF energy. It produces a high-frequency alternating current in the range of 100–500 kHz. Key features of generator are shown in Table 1.

The energy is delivered via an insulated needle containing an exposed tip. A ground plate, which has a large surface area, is connected to the patient and earthed whilst the patient's tissue acts to complete the circuit. The small surface area of the needle tip ensures a large current density and the large surface area of the ground plate ensures safety. A variety of RF techniques are used in clinical practice, including continuous thermal, pulsed, bipolar and cooled RF.

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Continuous thermal radiofrequency (CRF)

Mechanism of modulation

CRF lesioning occurs when a generated radiofrequency wave causes oscillation of charged ions, notably proteins, producing heat energy to be released. The heat produced leads to coagulation and thermal ablation of the surrounding tissue. It is important to note that the heat is generated by the tissue and absorbed by the electrode. The electrical field around the needle tip creates heat isotherms which dictate the size of the lesion.

Factors determining the size of the isotherms and the subsequent lesion are:

Temperature: there is no direct link between the voltage applied and the temperature generated and hence during lesioning the temperature and not voltage is controlled. Neuronal ablation occurs above 65°C so the temperature of the electrode is maintained at approximately 85°C to ensure that the surrounding tissue achieves this.

Duration of lesioning: the majority of the lesion is created within the first 60 seconds with some progressive expansion up to 90 seconds. After this the increased resistance impedes current flow and the lesion size fails to expand.

Size of the active tip: the diameter of the lesion is thought to be five times greater than the width of the tip. Thus a larger gauge needle with a longer active tip creates a larger lesion.

Heat wash out: heat is removed via blood vessels whereas bone is a good insulator. Therefore lesions near bone tend to be larger and of a more predictable size.

Clinical applications and evidence

A CRF lesion denatures a nerve and thus prevents electrical propagation. Thus nerves with a significant motor component tend not to be suitable for CRF. Most studies investigating the efficacy of CRF range in evidence between level 2b and 3. Table 2 shows a summary of some of the clinical uses of CRF.

Pulsed radiofrequency (PRF)

Mechanism of modulation

In PRF an alternating current is delivered in short bursts to target a nerve without producing a significant amount of heat and thermocoagulation. Typically a 50 kHz current is delivered in 20 ms pulses at a frequency of 2 Hz for 3–5 minutes. Heating is

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Features of RF generator

Feature	Function
Impedance monitor	Ensures completeness of circuit
Nerve stimulator	After placement of the needle the clinician uses the nerve stimulator function to ensure that the needle position is optimal. This is often done by initial stimulation at 50 Hz to stimulate sensory fibres and then at 2 Hz for motor fibres
Electrical system monitoring	Ensures electrical safety
Thermometer	This is usually via a thermocouple at the tip of the electrode. This is the hottest part of the lesion and ensures that adequate temperatures are obtained to create a lesion
Pulsed and continuous radio-frequency mode	Enables selection of mode

Table 1

minimized by keeping the electrode tip below 42°C. Furthermore heat is also dissipated during the pauses, principally through conduction and convection.

In PRF current density is greatest just distal to the active tip of the electrode and falls off rapidly within the first 0.1 mm. A wider weaker electrical field is also created around the cylindrical body of the electrode which also produces some clinical effects. This allows the electrode to be placed perpendicular to the nerve, making the procedure technically easier.

The mechanism by which PRF modulates pain remains unclear but it does not produce a histological lesion on the target nerve. Nerve modulation is likely to occur by the rapidly changing electrical field altering nerve conduction and gene expression affecting neuronal activation. Laboratory studies have demonstrated increased expression of activator genes and markers of cellular stress in neurones stimulated by PRF. More recently it has been shown that applying PRF to differentiated monocytes induces biological activity of TNF-α raising another possibility for the mechanism of action.

Clinical applications and evidence

Nearly any nerve or plexus can be targeted with PRF because of its non-destructive nature. This versatility and excellent safety profile makes it very appealing to clinicians. The procedures covered in Table 3 are by no means an exhaustive list but are some of the more topical and commonly performed.

Cooled radiofrequency

Mechanism of modulation

Cooled RF utilizes internally cooled RF probes to enlarge lesion size, therefore increasing the chance of complete denervation. CRF lesion size is limited by dissipation of current density and increase in tissue resistance secondary to thermocoagulation. By cooling the tissue adjacent to the electrode the current density is 'pushed outwards' and resistance of the surrounding tissue is reduced allowing for both an increase in the radius of the lesion and prolonging time above the thermocoagulation threshold. The lesion is also projected forward of the probe hence a perpendicular approach is possible (compared to CRF parallel approach). These factors combined increases the likelihood of complete neuronal ablation and a shorter procedure time.

Clinical uses of CRF

Region	Evidence
Lumbar medial branch denervation • For facetogenic lower back pain	Several RCTs show in quality of life variables, global perception of improvement, and generalized pain after 6 months improved[1] A Cochrane review in 2015 however stated that there was no high quality evidence to show that radiofrequency denervation provides pain relief or improves function for patients with chronic low back pain[2]
Cervical medial branch denervation • For facetogenic cervical pain and cervicogenic headaches	Several systematic reviews and an RCT support its use for cervicalgia. It is worth noting the only RCT for cervicalgia the patient group had whiplash and not degenerative disease[1] However, for cervicogenic headaches there are inconsistencies between RCTs and limited evidence means high quality data is lacking
Sacroiliac joint (SIJ) • SIJ dysfunction is estimated to cause approximately 30% of lower back pain	The SIJ can be difficult to denervate because of its variable and extensive innervation. A small RCT demonstrated 64% of patients who had their sacroiliac joint denervated had more than 50% reduction in VAS scores at 3 months.[3] With a growing body of evidence and new equipment available, this procedure is likely to be more widely performed
Genicular nerves • For chronic knee pain	A RCT for chronic osteoarthritis after successful diagnostic blocks demonstrated its potential use[4] along with numerous case series
Suprascapular nerves • For shoulder pain	It is more commonly treated with PRF because of the motor supply to the supraspinatus and infraspinatus muscles. However its use has been demonstrated in patients with very poor shoulder mobility
Gasserian ganglion • For trigeminal neuralgia	Although microvascular decompression is a more efficacious, RF can be used in high risk surgical patients with over 50% patients having relief at 5 years[5]

Table 2

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