Radiofrequency techniques in pain management

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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
- understand its clinical applications

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

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 while 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, cooled, bipolar and pulsed RF.

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 to 3. Table 2 shows a summary of some of the clinical uses of CRF.

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

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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 50Hz 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

approach). These factors combined increases the likelihood of complete neuronal ablation and a shorter procedure time.

Clinical applications and evidence

The indications for cooled RF are the same as for CRF; however, very few centres in the UK use it. Studies are limited and most randomized studies compare the results to placebo and not CRF. Table 3 summarizes some of the available evidence for this treatment.

Bipolar radiofrequency (BiRF)

Mechanism of modulation

Two electrodes of similar size are used instead of the conventional single electrode and grounding pad. Current density around both electrodes are similar and providing the electrodes are close enough together a ‘strip lesion’ is created. This allows the user to create the shape and location of the lesion to their requirements.

Clinical applications and evidence

The evidence is limited for its use in clinical practice. But BiRF of the facet joint capsule and of the lumbosacral discs may prove to be a safe and effective method of treating thoracic and lumbar back pain. More studies are needed though to show BiRF efficacy.

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 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

Clinical uses of CRF

Region	Evidence
Facet joint and sacroiliac joint denervation • For lower back pain	Despite several randomized controlled trials (RCTs) demonstrating quality of life, global perception and pain score improvements after 6 months, a Cochrane review in 2015 stated that there was only moderate and low-quality evidence to show that radiofrequency denervation improves pain or function for patients with chronic lower back pain[1] The SIJ can be difficult to denervate because of its variable and extensive innervation. However, with new technologies available it is becoming more popular. A small RCT demonstrated 64% of patients who had their sacroiliac joint denervated had more than 50% reduction in VAS scores at 3 months[2] Three large RCTs assessed facet joint, sacroiliac joints or intervertebral discs.[3] They assessed a standardized exercise programme with psychological support vs the programme plus radiofrequency denervation techniques over a 3-month period. They found no significant improvement in lower back pain. Some have criticized their methodology though
Cervical medial branch denervation • For cervical pain and cervicogenic headaches	Several systematic reviews and a RCT support its use for cervicalgia. It is worth noting the patient group in the RCT had whiplash and not degenerative disease[4] There are inconsistencies between RCTs for cervicogenic headaches and limited evidence means high quality data is lacking
Genicular nerves • For chronic knee pain	A RCT for chronic osteoarthritis after successful diagnostic blocks demonstrated its potential use[5] along with numerous case series
Gasserian ganglion • For trigeminal neuralgia	Although microvascular decompression is more efficacious, RF can be used in high-risk surgical patients with over 50% patients having relief at 5 years[6]

Table 2

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Clinical uses of cooled radiofrequency

Region	Evidence
Genicular nerve ablation • For the treatment of chronic knee pain	Both retrospective analyses and case series have shown improvements in self reported outcomes. This was supported by a prospective, multicentre, randomized crossover trial comparing cooled radiofrequency genicular ablation with steroid injections.[7] It found it was safe, effective and that study participants in the radiofrequency group had a significantly lower pain score at 6 months
Sacroiliac joints • SIJ dysfunction is estimated to cause approximately 30% of lower back pain	There are few randomized controlled trials for cooled radiofrequency in the management of sacroiliac joint pain. A meta-analysis commented on the heterogeneity of evidence published but concluded that it was safe and effective.[8] A randomized trial compared cooled radiofrequency to sham treatment demonstrated good outcomes at 12 months.[9]
Lumbar medial branch nerve denervation • For facetogenic lower back pain	A randomized prospective trial compared cooled with traditional radiofrequency ablation of medial branch nerves as a treatment for lumbar facet joint pain.[10] This found that both resulted in 50% success rate at 6 month follow-up with regards to improvement in pain and physical function; however, there was no significant difference between the two methods

Table 3

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

Clinical uses of pulsed radiofrequency

Region	Evidence
Greater occipital and third occipital nerve and sphenopalatine ganglion • For chronic head and facial pain, cervicogenic headaches	Several clinical studies have yielded promising results showing sustained improvement in pain relief, quality of life and reduced pain medication usage. RCT evidence is however lacking
Suprascapular nerves • For shoulder pain	Prospective and retrospective case studies have shown benefit. A small RCT showed a significant reduction in pain and disability index score and constant-Murley score at 6 months in PRF treatment versus lidocaine injection[11]
Glossopharyngeal nerve • This is common neuralgia in patients with oropharyngeal carcinomas and is difficult to treat due to rich innervation of the area and pain caused by functional movements	A prospective interventional clinical trial demonstrated significantly improved outcomes in 25 patients with oropharyngeal carcinoma who were treated with pulsed radiofrequency ablation of the glossopharyngeal nerve[12]
Ilioinguinal and genitofemoral nerves • Peripheral nerve entrapment • Post-surgical pain secondary to inguinal herniorrhaphy, caesarean section, appendectomy, and trauma to the lower quadrant of the abdomen or inguinal region	A double blind, sham controlled randomized trial with chronic post surgical orchialgia showed that PRF of the ilioinguinal nerve and genital branch of the genitofemoral nerve significantly lower pain as assessed by visual analog scale and significantly reduced use of analgesia[13]
Trapezius muscle • Myofascial Pain Syndrome	A study compared PRF with local anaesthetic alone in 36 patients and found that at 8 weeks pain was significantly lower in the PRF group[14]
Nerve root/dorsal root ganglion (DRG) • Radicular pain	Small RCT evidence and case series support the use of PRF to prolong the effects of nerve root and DRG injections

Table 4

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profile makes it very appealing to clinicians. The procedures covered in Table 4 are by no means an exhaustive list, but are some of the more topical and commonly performed.

Conclusions

Radiofrequency techniques have a wide range of applications in managing patients with chronic pain and must be carried out as part of a multidisciplinary approach. They offer more prolonged pain relief when compared to local anaesthetic and steroid injections and thereby facilitate further rehabilitation and enable patients to remain active and engage with physiotherapy and exercise. Although there is some evidence for its application, further high quality trials are needed. ◆

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