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ABOUT COVER

Editor-in-Chief of *World Journal of Clinical Cases*, Bao-Gan Peng, MD, PhD, is Professor and Director of the Department of Orthopedics at The Third Medical Center of PLA General Hospital. Professor Peng's research interest is spinal surgery. His career work has generated a multitude of new academic viewpoints and theories, and more than 200 academic papers, published both at home and abroad. In practice, he has systematically elucidated the pathogenesis of discogenic low back pain and established a new minimally invasive treatment method: The intradiscal methylene blue injection. He also revealed and characterized a new pathogenesis of Schmorl's nodes, which is a now a famous concept. Finally, he was the first to discover that ingrowth of Ruffini corpuscles into degenerative cervical disc is related to dizziness of cervical origin. (L-Editor: Filipodia)

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Expert consensus of Chinese Association for the Study of Pain on the radiofrequency therapy technology in the Department of Pain

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Abstract

On the basis of continuous improvement in recent years, radiofrequency therapy technology has been widely developed, and has become an effective method for the treatment of various intractable pain. Radiofrequency therapy is a technique that uses special equipment and puncture needles to output ultra-high frequency radio waves and accurately act on local tissues. In order to standardize the application of radiofrequency technology in the treatment of painful diseases, Chinese Association for the Study of Pain (CASP) has developed a consensus proposed by many domestic experts and scholars.

Key Words: Radiofrequency therapy; Standard radiofrequency therapy; Pulsed radiofrequency; Bipolar radiofrequency therapy; Expert consensus; Pain

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Core Tip: With the acceleration of global aging process, the number of patients with pain disorders is increasing. Radiofrequency therapy is an effective method for the treatment of pain related diseases. This paper reviews the basic principle, mode, parameters, and possible complications of radiofrequency technology.

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INTRODUCTION

Radiofrequency (RF) therapy is a kind of technology that uses special equipment and puncture needles to accurately output ultra-high frequency radio waves to act on local tissues, which can play the role of thermocoagulation, incision or nerve regulation to achieve the treatment of pain disorders. This minimally invasive treatment can be divided into standard radiofrequency (thermocoagulation) mode and pulsed radiofrequency (PRF) mode. Since the 19th century, animal experiments have used electric current to damage the nervous system. By the middle of the 20th century, the first radiofrequency generator with commercial application value came out^[1], which made the radiofrequency therapy technology applied in clinic. In 1997, Dutch physician Sluijter *et al*^[2] proposed PRF technology for the first time. PRF has great potential and application value in the treatment of painful diseases because it has no nerve injury, no hypoesthesia, soreness, burning pain and dyskinesia caused by nerve thermal dissection. It is the further development and supplement of traditional radiofrequency therapy technology. On the basis of continuous improvement and development in recent decades, the clinical application of radiofrequency therapy technology has been widely developed, and has become an effective means to treat all kinds of intractable pain.

In order to clarify the characteristics, advantages and disadvantages of RF therapy and to further standardize its application in the field of pain treatment, the proposed consensus was formulated specifically by several domestic experts and scholars organized by the Chinese Association for the Study of Pain (CASP).

BASIC PRINCIPLES OF RF THERAPY

RF therapy instrument (RFTI) generates RF current, which circulates through the body tissues between the tip of the working electrode in the affected area and the dispersion electrodes in other parts. The RF current flows through the tissues and generates a constantly changing electric field, which exerts a force on the electrolyte ions in the tissues and makes the ions move back and forth quickly. The friction and impact of ion currents in tissues generate magnetic field/heat, which is manifested as field effect/thermal effect in tissues^[3]. The temperature sensor at the tip of the RF electrode transmits the temperature signal of the treatment area back to the RFTI in real time. When the temperature of the treatment area reaches the pre-set temperature, the RFTI will automatically adjust the current intensity to maintain constant temperature of the working area, avoid fluctuations, and finally achieve the purpose of treatment^[4].

The field effect and thermal effect of RF determine the effect of RF therapy has been controversial. The direct current was commonly used in the early stage of RFTI, and its therapy effect was primarily derived from the thermal energy transformed by the resistance energy consumption of human tissues. Following the appearance of high-frequency alternating current RFTI, the thermal energy in the treatment area was mainly generated by the collision of the tissue molecules between the working electrode and the dispersion electrode resulted from alternating current. The molecular structure and physicochemical properties of pain-causing factors may be changed by molecular collision, leading to changes in the compliance of nerve conduction and the permeability of nerve cell membrane simultaneously, thereby producing therapeutic effects. Being restricted by the knowledge on direct current RF previously, more attention were paid to RF thermocoagulation in the early stage. With the in-depth understanding of the work principle of alternating current RF and the relationship among the three important parameters (frequency, field intensity and temperature), the role of PRF mode has been emphasized in recent decades. In PRF therapy mode, the RFTI emits electric current in the form of pulse, which is conducive to the maintenance of lower temperature of tissues around the needle tip. In this regard, it can exert superiority in long-term alleviation of pain and reduce the risk of complications from standard RF thermocoagulation. In recent years, in-depth research of clinicians and researchers has resulted in outstanding achievements, multiple newly established RF models have been emerging, such as unipolar and bipolar water-cooled RF, unipolar and bipolar manual PRF, four-needle RF, *etc.*, all of which have achieved satisfactory therapeutic outcomes^[5].

COMMONLY USED RF THERAPY MODES AND PARAMETERS

RF therapy mode^[6]

Standard RF therapy mode: Standard RF therapy mode (SRFTM) is also known as RF thermocoagulation or continuous RF mode, which is a continuous, low-intensity energy output mode. Current-induced thermal effects of SRFTM can block the transmission of pain signals owing to its effect on protein degeneration and nerve fiber destruction.

PRF therapy mode: PRF therapy mode (PRFTM) is a high-voltage and low-temperature radio frequency mode formed by discontinuous and pulsed current around the nerve tissue. The RFTI emits intermittent pulsed current to the needle tip, which exert an analgesic effect by the field effect caused by rapid voltage fluctuation of voltage near the nerve tissue. Simultaneously, the tip temperature of electrode is kept at 42 °C, which may not induce destruction on the motor nerve function. PRFTM can achieve analgesic effect without thermal nerve detachment effect.

Bipolar RF therapy mode: Bipolar RF therapy mode (BRFTM) consists of two electrodes to form a radio frequency circuit, which can produce a wider RF therapeutic area. According to different parameters and treatment objectives, it can be further divided into two types of bipolar standard RF and Bipolar PRF.

RF therapy parameters

The parameters commonly applied in RF therapy techniques include: needle tip temperature (°C), RF time (s), impulse frequency (H), output voltage (V) and pulse width (the duration of each RF current emitted, ms)^[7].

SRFTM: During standard RF therapy, the nerve fibers conducting pain and

temperature can be destroyed when the temperature in the treatment area exceeds 60 °C, and all nerve fibers can be destroyed no selectively when temperature higher than 85 °C. Accordingly, appropriate RF temperature can be selected according to the therapeutic purpose^[6].

PRFTM: The PRF parameters proposed earliest are the electrode tip temperature at 42 °C, pulse frequency of 2 Hz, pulse width of 20 ms, output voltage of 45 V and therapy duration of 120 s^[2]. In recent years, high-voltage long-term PRF (increasing output voltage and pulse time in PRF) have been applied in clinical practice. Supported by previous literature, it was reported that satisfied therapy effect could be realized when the bipolar pulse parameters pre-set as electrode tip temperature of 42 °C, pulse frequency of 2 Hz, pulse width of 20 ms, output voltage of 50-90 V, and therapy duration of 900 s^[8].

Bipolar SRFTM: In standard bipolar RF therapy, the needle tip distance can be set according to the length of the exposed end of the RF needle, the position relationship between the two needles, the therapeutic site and purpose. The distance between the two needle tips is usually 4-10 mm. To increase the thermotherapeutic effect, a wider banded damaged area can be produced by heat coagulation at 90 °C for 120-150 s^[6].

PRINCIPLES OF RF THERAPY

(1) Patients are identified as having pain in the corresponding innervated area; (2) Pain seriously affects patients' daily life or work; (3) Conservative treatments such as drugs are ineffective, or patients cannot tolerate the occurred adverse reactions; (4) Diagnostic nerve block is effective and pain is distributed locally; (5) Before treatment, the temperature and range of injury should be accurately predicted according to the patient's condition, and should be selected and controlled in the process of treatment; (6) The nerve should be accurately located under electrical stimulation and electrical resistance monitoring; (7) Repeat RF therapy can be adopted for patients with recurrent pain; (8) The following parameters should be strictly controlled during RF therapy: (a) Temperature The temperature of PRF is 42 °C, and standard RF is about 85 °C^[9,10]; (b) Treatment duration of RF The treatment duration of standard RF is generally 60-90 s per cycle, in a total of 2-3 cycles; and better therapeutic outcome can be realized with the duration of PRF therapy of 6min^[11,12]; (c) Size and shape of RF electrode The therapy range depends on the thickness and length of the exposed electrode; (d) Tissue property The electrode position can be determined according to the tissue resistance; and (e) Test sensory and motor tests should be performed before treatment to determine the relative position between RF needle and the nerve; (9) PRF therapy for pain should be initiated as early as possible, and the starting time of standard RF therapy remains to be studied in the future^[13]; (10) In the course of standard RF therapy, local anesthetics should be applied topically to relieve the pain caused by thermocoagulation; (11) Standard RF therapy should be used cautiously for nerves containing motor components to avoid the risk of damage to the motor function; (12) At present, there is still no gold standard for parameter setting of RF therapy, and massive high-quality studies are needed to provide the optimum therapeutic parameters; (13) It should be considered cautiously that cardiac arrest may occur in patients with pacemakers during RF therapy; (14) In patients with spinal cord electrical stimulator, it is necessary to prevent the spinal cord from being implicated by electrical current passing in the direction of the spinal nerve stimulator during RF therapy; and (15) Before RF therapy, the coagulation function of patients should be checked without abnormality, with additional confirmation of no infection at the puncture site and the whole body, and without mental disorder.

COMMON SITE OF RF THERAPY

The application of RF therapy in peripheral nerves

RF therapy of spinal nerve roots^[14]: RF puncture of spinal nerve roots should be conducted under the imaging guidance. The needle tip should be applied at the upper 1/3 of the corresponding intervertebral foramen. Unlike other spinal nerves, the sacral nerve should be punctured into the corresponding sacral foramen. After the tip reaches the target, sensory and motor tests should be conducted, which can induce

numbness, pain, abnormal sensation or muscle beating in the corresponding innervation area. Appropriate RF therapy mode of spinal nerve roots should be selected according to the pain situation. PRF can be used to treat postherpetic neuralgia, nerve root pain, post-nerve injury pain, postoperative incision pain, *etc.* In addition, patients with cancer pain often receive standard radiofrequency therapy, but the motor function of the corresponding innervated area and the motor dysfunction that may be caused by standard radiofrequency should be carefully evaluated to determine whether it has an intolerable impact on the patient's life.

RF therapy of nerve trunk: (1) The trigeminal branch^[15]. Trigeminal nerve includes maxillary nerve, mandibular nerve, supraorbital nerve and infraorbital nerve, *etc.* Standard RF or PRF will be selected according to the condition in the actual clinical practice. The puncture of maxillary nerve usually adopts the subzygomatic arch approach. The position of the foramen rotundum should be determined under the guidance of X-ray or other images, and the direction of the tip should be adjusted according to the guidance of imaging. When the needle inserting about 5-6 cm depth, it can reach the external orifice of foramen rotundum, and radiating pain will appear in the distribution area of maxillary nerve. The puncture of mandibular nerve should be guided by image through the subzygomatic arch approach (puncture depth of about 5-6 cm) or through the traditional Hartel anterior approach (puncture depth of about 5-8 cm) under the guidance of imaging. Radiating pain may occur in the distribution area of the mandibular nerve when puncture needle touching mandibular nerve. Supraorbital nerve puncture can be performed through the supraorbital foramen approach, and the supraorbital nerve can be reached when it is inserted into the skin of 0.5-1 cm in depth vertically. Infraorbital nerve puncture is performed through the infraorbital foramen approach. The suborbital foramen can be entered when it is inserted into the skin of 1-3 cm in depth at an oblique-posterior-superior direction. The puncture depth can be maintained at just about 1-2 cm to avoid injury to the eyeball. Sensory and motor tests should be carried out after the puncture needle reaches the target nerve. Sensory tests can induce numbness or pain in the corresponding innervation area. During the exercise test, the other trigeminal nerve branches have no motor response except that the mandibular nerve can induce mandibular beating. Standard RF parameters include temperature at 60-80 °C for a duration of 60-90 s. PRF parameters are temperature at 42 °C, duration of 120-240 s, pulse width of 20 ms, and frequency of 2 Hz, in a total of 2-3 cycles. RF of trigeminal nerve branches can be used to treat trigeminal neuralgia, trigeminal neurogenic pain, trigeminal post-herpes zoster pain, cancerous facial pain, and atypical facial pain, *etc* ^[16]; (2) Glossopharyngeal nerve^[17]. Under the guidance of imaging, the needle should be penetrate vertically toward to styloid process from the midpoint of the line between the apex of mastoid process and the mandibular angle. The styloid process can be normally encountered by the needle at about 1.5-3 cm depth, and then slipped slightly forward and upward about 0.5 cm to reach the lower part of the jugular foramen. During the location of the glossopharyngeal nerve *via* sensory and motor tests, sensory test can induce throat numbness or pain and motor test can induce cough. The position of the needle should be adjust in the case of diaphragm twitch. RF of glossopharyngeal nerve should give priority to PRF, with similar PRF parameters as those mentioned before. The RF of glossopharyngeal nerve can be used for the treatment of glossopharyngeal neuralgia, pharyngeal and laryngeal cancer pain, and and pharyngeal and laryngeal pain caused by tumors of skull base; (3) The dorsal ramus of spinal nerve^[18]. The posterior branches of the spinal nerve include 31 pairs composing of the cervical, thoracic and lumbar nerves. The posterior branches of the cervical nerve and the lumbar nerve are often selected for RF therapy. The posterior branch of C1 nerve is the suboccipital nerve, which is the motor nerve, and the posterior medial branch of C2 nerve is the occipital great nerve. The PR target of the posterior branch of cervical nerve below C3 nerve locate at the midpoint of the corresponding joint column. The PR target of the posterior branch of the lumbar nerve locate at the junction of the superior articular process root and transverse process of the corresponding vertebral body. During the puncture, the needle should be punctured to the target of the posterior branch of the corresponding spinal nerve under the guidance of imaging. Sensory and motor tests should be carried out after the needle tip reaches the target position. Sensory test can induce numbness, acid distension or pain in the corresponding innervation area, and motor test may cause paravertebral muscle beating. The standard RF or PRF can be applied on the posterior ramus of spinal nerve, with similar parameters as those mentioned before. RF of the posterior ramus of the spinal nerve is applicable for the treatment of neck and shoulder pain, lumbar and leg pain, lumbar facet joint syndrome, compression syndrome of the posterior ramus

of the spinal nerve, *etc.*; and (4) Other peripheral nerves. With the popularity of PRF, the therapy is increasingly applied to peripheral nerves, such as occipital and intercostal nerves. Occipital nerve puncture can be conducted under the guidance of ultrasound, with the insertion point located at the midpoint of the line between the posterior mastoid process and the axial spinous process. The puncture should be perpendicular to the occipital bone surface, parallel to the longitudinal axis of the spine, and penetrates into the occipital bone surface slowly. Intercostals nerve puncture can also be performed under the guidance of ultrasound, the puncture needle should be inserted along the lower edge of ribs to the head side (about 20 ° in direction), slipping through the edge of the ribs, and then needling 2-3 mm to reach the subcostal sulcus. Sensory and motor tests should be performed after the needle reaches the target nerve. Occipital nerve RF can be used to treat occipital neuralgia, cervical headache^[19], postherpetic neuralgia in the distribution area of C2 nerve, *etc.* Intercostal nerve RF can be used for the treatment of postherpetic neuralgia and postoperative incision pain.

Peripheral nerve RF therapy: (1) The peripheral nerves of the scalp. Scalp peripheral neuroma has a relatively low incidence but severe pain^[20]. RF of scalp peripheral nerve can be considered for patients who are effective but not compliant. With local anesthesia of the puncture point, RF puncture needle should be punctured along the point into the subcutaneous layer with the performance of sensory test at the same time. The puncture should be stopped when the original pain or abnormal feeling is induced, followed by motor nerve test with attention paid to the avoidance of damage to the motor nerve. The RF of the nerve endings of the scalp can be in the form of PRF or standard RF, with the same parameters as before; and (2) Peripheral nerve of stump. It is mainly used to treat patients with residual limb pain and phantom limb pain. Ultrasound-guided puncture is commonly adopted in RF therapy for the treatment of patients with residual limb peripheral nerve. After local anesthesia, patients may usually have pain reactions when the puncture needle was inserted into the residual limb neuroma. Sensory and motor tests should be performed subsequently, of which sensory nerve test can induce original pain or paresthesia, and motor test can stimulate muscle twitches. Standard or PRF may be used. Under standard RF, the parameters are temperature at 60 °C within a duration of 90 s, followed by gradual increase in the temperature, every 10 °C for a period, until reaching 90 °C. Multiple cycling treatment should be applied and the surgery should be continued until the presence of strong echo mass in the whole neuroma of the patient indicated by ultrasound^[21]. PRF parameters should be set as before.

The application of RF therapy in ganglia

RF therapy of spinal ganglia^[22,23]: PRF is generally used in dorsal root ganglion of spinal nerve. Under the guidance of imaging, the RF puncture needle should be punctured to the posterior 1/3 of the intervertebral foramen (below the inferior notch of the upper vertebral pedicle). The C2 dorsal root ganglion is located in the central posterior area of the atlantoaxial joint and its position is fixed. RF puncture needle should be punctured from the back to the central point of the atlantoaxial joint under the guidance of imaging. Sensory and motor tests should be performed after reaching the target of the needle point. Sensory tests can induce numbness or pain in the corresponding spinal innervation area; Motion test can sometimes cause muscle beating in the corresponding spinal innervation area PRF of dorsal root ganglion of spinal nerve can be used to treat postherpetic neuralgia, nerve root pain, cervicogenic headache, pain after nerve injury, postoperative incision pain, *etc.* Standard RF may also be used in patients with cancer pain.

Cranial ganglion RF therapy: (1) Trigeminal gasserian ganglion. RF technology of trigeminal semilunar ganglion has become one of the main treatment methods for primary trigeminal neuralgia^[24,25]. The main indications are: (a) Patients with primary trigeminal neuralgia involving branches II and III of the trigeminal nerve, patients with poor efficacy of drug therapy, and those who are unable to continue to be treated with drugs or are not effectively treated of peripheral branches; (b) Atypical facial pain accompanied by pain in the innervation area of trigeminal branches II and III; (c) Involvement of the trigeminal nerve in the advanced cancer pain; (d) Ineffective surgical treatment of secondary trigeminal neuralgia; and (e) Patients with recurrent trigeminal neuralgia. Simple pain in the innervation area of trigeminal branch I, with no trigeminal semilunar RF in principle. RF therapies include standard RF^[26] and PRF^[27,28]. Brief operation steps are described as follows: The patient should be informed to keep the supine position. In the case of operation guided by X-ray, the projection

angle should be adjusted to 30 degrees at the top of the chin, 21 degrees at the lateral position, and the projection of the foramen ovale on the cheek should be used as the puncture point. When guided by computed tomography (CT), the traditional Hartel anterior approach or modified Hartel anterior approach can be adopted to select the position 2.5-3.0 cm from the lateral side of the diseased side for puncture. Generally, the puncture of the foramen ovale will induce severe facial pain, needle tip fall, and a sense of toughness like penetrating the rubber. Impedance value is commonly in 300-500 Ω ; Sensory test can induce pain in the innervating area of the affected trigeminal nerve. According to the motor test, corresponding masticatory muscle movement can be induced in patients with the involvement of trigeminal nerve branch III, but no similar performance in patients with branch II involvement alone. Standard RF parameters should be set as before. Compared with the standard RF, PRF shows milder degree of tissue injury, and lower possibility of complications. However, for primary trigeminal neuralgia, the effect of PRF is worse than that of standard RF, and the long-term effect needs to be further evaluated; (2) Sphenopalatine ganglia. The indications for RF therapy of sphenoid palatal ganglion are as follows^[29,30]: (a) Cluster headache; (b) Migraine; (c) Residual forehead headache after treatment for cervicogenic headache; (d) Atypical facial pain in the maxillary nerve region; and (e) Other pain syndromes (poorly located head and face headaches with parasympathetic manifestations of pain, head and face pain caused by head and face tumors, *etc.*). It should be emphasized that RF therapy of sphenopalatine ganglion should be performed until the confirmation of effective diagnostic block. The zygomatic arch approach is usually adopted. The puncture point should be located 3-4 cm in front of the tragus of the affected side and 0.5-1 cm below the zygomatic arch notch. After determining that the puncture needle enters the pterygopalatine fossa under the guidance of imaging, sensory and motor tests should be given respectively. During sensory test, the patient will feel ache and swelling pain in the deep side of the nasal root. During the motor test, the optimum puncture position is at the voltage above 1.0 V with no stimulation of facial twitch. After accurate measurement and localization, PRF mode is commonly used in the treatment of sphenopalatine ganglion. If the standard RF mode is adopted, the treatment parameters should be selected to transit from at 60 °C for 60 s to at 70 °C for 60 s, and then gradually rise to at 75 °C for 120 s, in a total of 1-2 cycles; and (3) Sympathetic ganglia. During RF therapy of sympathetic ganglia, puncture can be performed under the guidance of ultrasound, fluoroscopy or CT. RF thermocoagulation of cervical, thoracic or lumbar sympathetic ganglion can block the transmission of sympathetic nerve excitation and hence exert a therapeutic effect on neuropathic pain and complex local pain symptoms^[31]. Lumbar sympathetic neurofrequency thermocoagulation has definite curative effect on intractable pain of thromboangiitis obliterans, diabetic complications of lower limb vascular disease, peripheral neuropathy, complex local pain syndrome and intractable burning pain of lower limbs^[32,33]. In view of the extensive effects of sympathetic nerve, PRF with neuromodulatory effects on the cervical sympathetic chain can be used to treat complex regional pain syndrome. RF pulse of lumbar sympathetic ganglion can relieve neuropathic pain of lower limbs. RF therapy of coccygeal ganglion can successfully relieve perineal pain caused by tumors, and which has been reported primarily to be effective for coccygeal pain. However, there is still limited high-quality evidence concerning current use of sympathectomy for neuropathic pain and complex regional pain syndrome. Sympathectomy should be used prudently and is recommended to be selected only when other treatment options are not available.

Application of RF therapy in intervertebral disc

RF therapy of intervertebral disc is a commonly used minimally invasive treatment method and has been relatively mature, with the advantages of simple operation, less intraoperative injury, obvious curative effect, high safety, repeated treatment, less damage to the stability of the spine structure^[34]. RF imaging of the intervertebral disc should be performed under fluoroscopy or CT guidance. Single needle RF thermocoagulation can be used to treat discogenic pain. Furthermore, RF combined with low-dose collagenase injection through anterior cervical approach can be used for the treatment of cervical disc herniation^[35]. RF ablation nucleoplasty of cervical intervertebral disc may also be used for the treatment of cervical vertigo. RF thermocoagulation of lumbar disc herniation includes single-needle RF, double-needle RF and water-cooled RF. Among them, the water-cooled bipolar RF applies water-cooled system that not only expands the scope of action and improves the effect on the premise of ensuring the safety. PRF of the lumbar disc is a novel technique that may be a therapeutic option for patients with discogenic low back pain.

The application of RF therapy in joints

RF therapy of shoulder joint^[36]: PRF has been widely used in the treatment of shoulder joint pain. The scapular nerve PRF is the most widely used one. Systematic evaluation showed that PRF therapy for shoulder joint pain was effective for at least 12 wk without significant complications. However, it is still unclear whether the effect of this therapy is better than other therapies such as intra-articular injection of cortisol hormone and percutaneous electrical stimulation. The subscapular nerve PRF has certain curative effect, and the intra-articular RF also has certain curative effect, but the disadvantage is that there is no support from the results of randomized controlled trials.

RF therapy of sacroiliac joint^[37]: It is estimated that 10% to 25% of chronic low back pain is originated from the sacroiliac joint. Conventional RF model has certain effect on the sacroiliac joint pain. In recent years, there have been many attempts to use hypothermic RF mode in clinical practice. However, there are few reports on the application of PRF in sacroiliac joint pain. Bipolar RF can form a band-like damage zone behind the sacroiliac joint, inactivate the joint dorsal nerve, and achieve the purpose of pain treatment.

RF therapy of facet joints^[38]: Facet joint disorder is a common cause of low back pain, Interruption of the posterior medial ramus of the spinal nerve by standard RF ablation is an effective approach for pain treatment, and its effect is superior to that of conventional glucocorticoid injection. PRF has also been shown to have a better therapeutic effect, but its pain relief time is shorter than that of the standard RF. It still has good clinical application value in view of its repeatable and non-destructive characteristics.

RF frequency of knee joint^[39]: In the treatment of knee osteoarthritis pain, RF therapy has a variety of applications for intra- and peri-articular innervation of the nerve, and have certain therapeutic effects. Intra-articular RF is performed through either direct puncture or under the guidance of arthroscope to ablate intra-articular lesions or PRF regulation. Other RF modalities include RF regulation of the saphenous nerve, sciatic nerve, tibial nerve, common peroneal nerve, and periarticular nerve plexus. In recent years, ultrasound-guided RF therapy has been widely used in knee joint to achieve more accurate and effective treatment.

Application of RF therapy in soft tissue

Soft tissue pain is one of the common diseases in the pain department. There are many causes of soft tissue pain, including primary and secondary pain. Primary factors include sequelae of acute soft tissue damage and pain response induced by chronic soft tissue damage. Secondary common causes include acute or chronic soft tissue injury, secondary muscle spasm or muscle contracture. Accordingly, it may cause nerve damage or innervation disorders, leading to a series of complex biomechanical and neurophysiological effects between vertebrae and joints, thus resulting in a wide range of persistent chronic soft tissue pain.

There are many effective methods to treat soft tissue pain, including acupuncture and moxibustion, massage, manipulation, physiotherapy, silver needle, acupotomy, nerve tissues, *etc.* At present, RF therapy of soft tissue is mainly based on the theory of soft tissue stimulus point or tenderness point and the theory of implicated pain and muscle twitching. The treatment sites mainly focus on the starting and stopping point of the muscle, such as the connection between the muscle and fascia and periosteum, the muscle abdominal position of the muscle, the osteofascial compartment or osteofascial canal, the sepal area between the bone and the muscle fascia, *etc.*

RF therapies for soft tissue pain include standard RF and PRF^[40,41]. At present, standard RF is more widely used in the treatment of soft tissue pain than that of PRF. Standard RF therapy can produce high temperature in tissues and damage to the cell by protein coagulation within the treatment range. When RF needle reaches the corresponding treatment point of soft tissues during treatment, it can produce the function of separating tissue adhesion, releasing contracture and promoting local tissue blood supply. Standard RF parameters generally include temperature of 50-80 °C and working duration of 80-120 s, and those of PRF therapy are temperature at 42 °C and working duration of 120-900 s. RF therapy may have broad prospects in soft tissue pain treatment since its tip temperature can be maintained at 42 °C with no any damage to surrounding tissues and nerves.

COMPLICATIONS AND PRECAUTIONS OF RF THERAPY FOR PAIN DISORDERS

Complications^[42]

The complications include: (1) Nerve injury; (2) Vascular injury and bleeding; (3) Hypotension; (4) Infection; (5) Skin burn; and (6) Complications of RF therapy in different parts.

Complications of RF therapy for trigeminal neuralgia and semilunar ganglion^[43]: (1) Facial sensory disturbance. The incidence of facial sensory disturbance is as high as 94% during standard RF thermocoagulation, with most patients presenting with hypoesthesia or numbness. It also provides evidence that pain can only be removed when the sensation in the corresponding trigeminal innervation area decreases significantly or disappears during RF therapy; (2) Eye damage. Eye damage is predominated by hypocorneal reflex (incidence of 3%-27%). Neuropathic palsy is evident in 1%-5%. If corneal reflex is absent, blindfold should be applied or the eyelid should be sutured immediately. The incidence of double vision is estimated to be 0.3%-3%; (3) Trigeminal motor branch injury. The main manifestations for trigeminal motor branch injury are weakness of masseter or pterygoid muscles and masticatory disorders. It can be usually recovered after 6 to 9 wk; (4) Internal carotid artery injury. It is but quite critical, and surgery should be stopped once occurs and replaced by close observation. Patients with severe bleeding should be treated by surgery; (5) Leakage of cerebrospinal fluid. Leakage of cerebrospinal fluid is extremely rare and can form subcutaneous hydrops in parotid ministry mostly. It can be cured commonly by using puncture-aspiration and pressure dressing; and (6) Others. Other situations also include cranial nerve palsy, arteriovenous fistula, meningitis, saliva secretion abnormalities, *etc.*

Complications of RF therapy for disc herniation^[44]: (1) Intervertebral infection. Sterility should be strictly controlled and antibiotics should be used before and after the operation; (2) Thermal injury of vertebral endplate. The puncture needle should be placed in the middle part of the intervertebral space, with the positive position of the needle tip not exceeding the inner edge of the vertebral arch, and the lateral position should be located at the back 3/4 of the intervertebral space; (3) Electrode broken. Careful examination should be carried out before the operation, and gentle operation should be performed during the operation; (4) Injury of blood vessels. It can lead to retroperitoneal hematoma, lumbar major hematoma, mediastinal hematoma, *etc.*, with an incidence of 1.7%. During the operation, the number of puncture should be reduced as much as possible. After the removal of the puncture needle, the needle channel should be compressed to prevent hematoma from forming in the deep part of the pinhole.

Matters needing attention^[45]

The premise of RF therapy: (1) Patients with localized pain and effective diagnostic block; (2) Patients with identified local sources of pain, such as pain in the innervation areas caused by facet joints, intervertebral discs, musculoaponeurosis, tumors, or other causes; (3) Patients with chronic pain who are unable to respond to non-invasive conservative treatment, to respond well to medication, or to tolerate or unwilling to use medication due to side effects of medication or treatment; (4) Patients with pain that has affected the normal life or work, such as interfering with sleep, or the patient with psychological abnormalities, such as anxiety, depression and anger that need to implement behavior therapy; (5) Patients who require RF therapy due to ineffective results by other conservative treatment; and (6) Patients without contraindications for puncture therapy, such as coagulation dysfunction, and those who can be cooperative to the treatment.

Patients with pacemakers and patients with spinal cord electrical stimulators: (1) Patients with pacemakers should be aware that cardiac arrest may occur during RF therapy; and (2) Patients with spinal cord electrical stimulators need to prevent the spinal cord from being implicated when the electrical current passes along the direction of the spinal nerve stimulator during neck operation.

The hemodynamic in the elderly: The hemodynamic in the elderly is unstable, additional attention should thus be paid since RF therapy of the posterior root node may affect the blood supply to the adjacent spinal cord due to changes in local blood circulation, resulting in incomplete paralysis of the opposite side of the RF site.

GRADING OR RATING THE QUALITY OR STRENGTH OF EVIDENCE

The qualitative modified approach to grading of evidence and guide for strength of recommendations are shown in [Table 1](#) and [Table 2](#).

CONCLUSION

To sum up, the current domestic and foreign RF therapy technology is no longer simply thermal coagulation damage, but replaced by non-destructive PRF therapy with increasingly more extensive range of use, thus expanding the application of RF therapy technology in the treatment of chronic pain diseases. In this paper, the basic principle of RF technology, commonly used RF modes and parameters, principles and locations of RF technology application, as well as the possible complications and matters needing attention are summarized based on the literature of RF therapy at home and abroad and the experience of some experts. The consensus of RF therapy technology of doctors in the Department of Pain is reached eventually, which will play a normative and guiding role in the treatment of painful diseases by RF technology in China.

Table 1 Qualitative modified approach to grading of evidence^[46]

Grading	Qualitative	Evidence
Level I	Strong	Evidence obtained from multiple relevant high quality randomized controlled trials for effectiveness
Level II	Moderate	Evidence obtained from at least one relevant high quality randomized controlled trial or multiple relevant moderate or low quality randomized controlled trials
Level III	Fair	Evidence obtained from at least one relevant high quality nonrandomized trial or observational study with multiple moderate or low quality observational studies
Level IV	Limited	Evidence obtained from multiple moderate or low quality relevant observational studies
Level V	Consensus based	Opinion or consensus of large group of clinicians and/or scientists for effectiveness as well as to assess preventive measures, adverse consequences, effectiveness of other measures

Table 2 Guide for strength of recommendations^[47]

Strength	Recommendations
Strong	There is high confidence that the recommendation reflects best practice. This is based on: (1) strong evidence for a true net effect (<i>e.g.</i> , benefits exceed harms); (2) consistent results, with no or minor exceptions; (3) minor and/or few concerns about study quality; and/or (4) the extent the panelists' agreement. Other compelling considerations (discussed in the guideline's literature review and analyses) may also warrant a strong recommendation.
Moderate	There is moderate confidence that the recommendation reflects best practice. This is based on: (1) good evidence for a true net effect (<i>e.g.</i> , benefits exceed harms); (2) consistent results, with minor and/or few exceptions; (3) minor and/or few concerns about study quality; and/or (4) the extent of panelists' agreement. Other compelling considerations (discussed in the guideline's literature review and analyses) may also warrant a moderate recommendation.
Weak	There is some confidence that the recommendation offers the best current guidance for practice. This is based on: (1) limited evidence for a true net effect (<i>e.g.</i> , benefits exceed harms); (2) consistent results, but with important exceptions; (3) concerns about study quality; and/or (4) the extent of panelists' agreement. Other considerations (discussed in the guideline's literature review and analyses) may also warrant a weak recommendation.

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