Review Article

Efficacy of pulsed radiofrequency in controlling pain caused by spinal disorders: a narrative review

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Abstract: Pulsed radiofrequency (PRF) stimulation has been safely and effectively applied for controlling various types of pain. Here, we aimed to systematically review the literature pertaining to the efficacy of PRF stimulation for managing pain associated with spinal disorders. We conducted a PubMed search for papers published until August 20, 2019, that used PRF to treat pain resulting from spinal disorders. The following inclusion criteria were applied when selecting the articles: (I) patients' pain was caused by spinal disorders; (II) PRF stimulation was applied on the spinal structure; and (III) after PRF stimulation, follow-up evaluation was performed to assess the change in pain intensity. Review articles were excluded. The primary literature search yielded 168 relevant papers. After reading their titles and abstracts and evaluating their eligibility based on the full-text articles, we finally included 59 publications in this review. The therapeutic outcomes reported in the selected studies showed that PRF is an effective treatment for cervical and lumbar radicular pain. Similarly, PRF stimulation seems to be effective for treating cervical joint (cervical facet and atlanto-axial joints) pain and lumbar facet joint pain. PRF stimulation has also resulted in positive outcomes in some studies, in which patients were treated for other disorders, including cervicogenic headache, discogenic neck pain, thoracic facet joint pain, discogenic back pain, and coccydynia. Nevertheless, there is insufficient evidence for the efficacy of PRF stimulation in these disorders. In conclusion, our review provides insights into the degree of evidence available on the effectiveness of PRF stimulation for treating pain associated with each of the spinal disorders reviewed. This information will help clinicians make informed decisions on using PRF stimulation to treat various spinal conditions and manage the associated pain.

Keywords: Cervicogenic headache; coccydynia; discogenic pain; joint pain; pulsed radiofrequency (PRF); radicular pain; spinal disorder.

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Introduction

Pain caused by spinal disorders is common in the human population, resulting in functional impairment and decreased quality of life (1). Spinal pain includes axial pain and radicular pain. Axial pain originates mainly from the disc and the facet joints. Radicular pain is caused by irritation of the sensory root or the dorsal root ganglion (DRG) of a spinal nerve. Several therapeutic methods, including oral medications, modalities, and corticosteroid injections, are being used to treat spinal pain (1). However, in some patients, the pain does not respond to these treatment methods. Moreover, oral pain-relief medication can cause adverse effects in the gastrointestinal, renal, or cardiovascular systems. Corticosteroid injections have several adverse effects as well, including tissue atrophy, fat necrosis, degeneration of the articular cartilage, hyperglycemia, hematoma, vascular necrosis, and injection (1).

Pulsed radiofrequency (PRF) stimulation can safely and effectively control various types of pain (2-6). Continuous radiofrequency (CRF) stimulation exposes the target nerves to continuous electrical stimulation, which subsequently increases the temperature around the radiofrequency needle tip, causing a lesion in the target nerve and ablates the surrounding structures. In contrast, PRF stimulation uses radiofrequency currents to produce heat bursts, with long resting phases between them; therefore, the tissue temperature does not increase beyond 42 ℃, which prevents irreversible tissue damage (2-6). The exact mechanism of pain reduction by PRF stimulation has not yet been fully elucidated, but some possible mechanisms have been proposed. PRF stimulation inhibits the propagation of pain impulses by decreasing microglial activity and increasing c-fos expression in the dorsal horn. Together, these sustain the activation of pain-inhibitory mechanisms (7,8). Moreover, downregulation of microglia after PRF stimulation was reported. Because microglia contribute to the development of chronic pain by releasing several cytokines that mediate the pain signal, downregulating the microglia might prevent the progression to chronic pain (7). Additionally, PRF stimulation causes microscopic damage to the principal sensory nociceptive sensory fibers (C-fibers and A-delta fibers), but rarely damages the larger non-pain-related sensory fibers (A-beta fibers) (9). Finally, PRF stimulation was reported to enhance the noradrenergic and serotonergic descending pain inhibitory pathways (2).

Herein, we review published studies to establish the effectiveness of PRF stimulation in managing pain caused by spinal disorders.

Methods

We searched the MEDLINE database (PubMed) for articles published until August 20, 2019, by using the following key phrases: (PRF AND spine) OR (PRF AND radicular pain) OR (PRF AND radiculopathy) OR (PRF AND facet joint) OR (PRF AND discogenic pain) OR (PRF AND atlanto-occipital joint) OR (PRF AND atlanto-axial joint). Articles meeting the following inclusion criteria were selected: (I) patients' pain was caused by spinal disorders; (II) PRF stimulation was applied on the spinal structure; (III) after PRF stimulation, follow-up evaluation was performed to assess the change in pain intensity. Review articles were excluded.

Results

The primary literature search yielded 168 relevant papers. After reading their titles and abstracts, and assessing their eligibility based on the full-text articles, we included 58 publications in this review. Among the included studies, 22 reported applying PRF stimulation for cervical spine disorders [radicular pain, 13 (10-22); joint pain, six (3,23-27); discogenic pain, one (28); cervicogenic headache, two (29,30)]. PRF stimulation was also applied for lumbar spine disorders in 37 studies [radicular pain, 23 (11,15,16,31-50); joint pain, ten (24,51-59); discogenic pain, four (60-63)]. Pain due to thoracic spine disorders was treated with PRF stimulation in one study (64), and that due to coccydynia was treated with PRF stimulation in three studies (65-67).

Discussion

Cervical spine disorders

Pain caused by cervical spine disorders includes radicular pain, joint (facet, atlanto-occipital, and atlanto-axial) pain, discogenic pain, and cervicogenic headache.

Cervical radicular pain

The leading causes of radicular pain are herniated disc or spinal stenosis that induce chemical inflammation and mechanical compression of the nerve root (68). Thirteen studies reported using PRF stimulation for cervical radicular pain; all studies conducted PRF stimulation of the cervical dorsal root ganglion (DRG) and showed a positive pain-reduction response (10-22). Four of these studies were randomized controlled trials (RCTs) (14,15,18,20). Van Zundert *et al.* (18) showed better treatment outcomes in the 11 patients who received PRF stimulation treatment than in the 12 patients who received sham treatment. The assessment was done three months after the treatment. Lee *et al.* (15) also performed a 3-month follow-up and reported similarly positive treatment response in the ten patients treated with PRF stimulation and in the eight patients who received transforaminal epidural steroid injection (TFESI). Wang *et al.* (20) reported better treatment outcomes with combination therapy of PRF stimulation and TFESI than with either of them alone. Halim *et al.* (14) compared the pain-reduction effect between PRF stimulation and percutaneous nucleoplasty in 34 patients. Both procedures successfully reduced cervical radicular pain and had sustained effect for at least three months, with no significant intergroup differences. These RCTs show that PRF stimulation could be used for managing cervical radicular pain, and that the addition of TFESI to the treatment could enhance its effect. Among the other nine studies, three were prospective observational studies that showed a significant decrease in the initial pain (12,13,17). Choi *et al*. reported a sustained PRF stimulation effect for one year (12). In their study, 14 of 21 patients showed pain relief of ≥50% when assessed one year after the application of PRF stimulation to the cervical DRG. Four retrospective studies (11,16,21,22) and two case reports (10,19) also showed that PRF stimulation could effectively control cervical radicular pain. Interestingly, Chang conducted bipolar PRF stimulation in two patients whose pain could not be controlled by combination therapy of monopolar PRF stimulation and TFESI (10). Bipolar PRF stimulation successfully controlled the pain, with the effects lasting at least six months. These favorable outcomes indicate that PRF stimulation is a good therapeutic option for managing cervical radicular pain.

Cervical joint pain

Six studies reported performing PRF stimulation to control pain in the cervical joints, including the atlanto-occipital and cervical facet joints (3,23-37). PRF stimulation was performed using medial branch stimulation (23,24) or intra-articular stimulation (3,25-27). PRF stimulation of the medial branch of the cervical posterior primary ramus was successful in inhibiting pain signal transmission from the facet joint to the brain (23,24). In intra-articular PRF stimulation, owing to the insulating property of the bone, the current produced by the PRF stimulation was deflected by bony surfaces and thus remained within the joint space, without any reduction in intensity (3,25-27). The current in the joint space could thus inhibit the excitement of the nociceptive nerve fibers present in the synovial lining of the joint (3,25-27). Lim *et al*. (3) performed intra-articular PRF stimulation in 20 patients and intra-articular corticosteroid injection in 20 patients. Both treatments performed equally well at reducing the patients' pain when assessed one, three, and six months after treatment. Shin *et al*. (25) conducted intra-articular PRF stimulation (12 patients) or intra-articular corticosteroid injection (11 patients) to treat atlanto-occipital joint pain. Both procedures showed positive effects in reducing the atlanto-occipital joint pain, and their effects persisted for at least six months. No significant intergroup differences were reported. Moreover, Liliang *et al*. (23) conducted a prospective observational study to evaluate the effect of PRF stimulation of the cervical medial branch on neck pain due to whiplash in 14 patients. At the 1-year follow-up, nine patients (64.3%) showed significant pain reduction. Two retrospective studies and one case report (24,26,27) showed substantial pain reduction after a medial branch or intra-articular PRF stimulation. These outcomes suggest that PRF stimulation is effective in patients with cervical joint pain. Despite these favorable treatment outcomes, additional prospective clinical trials would be required to ascertain the usefulness of PRF stimulation in the treatment of cervical joint pain.

Cervicogenic headache and discogenic neck pain

PRF stimulation of the C2 DRG is used for managing cervicogenic headaches. The C2 DRG is a common clinical target for various types of headache treatment (69). The medial branch of the C2 spinal nerve dorsal ramus becomes the greater occipital nerve, which is the primary sensory nerve of the skull occipital area (69). Considering the convergence in the trigeminal nucleus in the upper cervical segments, inhibiting the transmission of nociceptive information in the C2 DRG by PRF stimulation should be able to resolve cervicogenic headache (69). Zhang *et al*. (30) reported of two patients whose cervicogenic headache was successfully resolved after PRF stimulation of the C2 DRG. Li *et al*. (29) found that, when treating patients with cervicogenic headache, interlaminar epidural steroid injection, combined with PRF stimulation of the C2 DRG, had a better effect than did treatment with epidural steroid injection alone.

Additionally, Kwak *et al*. (28) performed C4-C5 intradiscal PRF stimulation in a patient with a discogenic neck pain that scored 7 on a numeric rating scale (NRS). Two weeks and one month after the PRF stimulation, the patient had no pain at all, and two months after the PRF stimulation, the NRS score was 2.

Although the aforementioned studies imply that PRF stimulation is useful in treating these conditions, more definitive evidence from trials assessing PRF stimulation as a treatment for cervicogenic headache and discogenic neck pain is needed.

Thoracic spine disorder

Only one study reported of pain caused by a thoracic spine disorder that was treated with PRF stimulation (64). Chang (64) performed a prospective study, using PRF stimulation of the thoracic medial branch of the dorsal ramus in 20 patients with chronic thoracic facet joint pain that was refractory to medial branch block with local anesthetics. Three months after the PRF stimulation, 11 patients (55%) showed ≥50% reduction in their pain score, with the average NRS score going down from 6 before the treatment to 4 three months after the treatment. The extreme scarcity of PRF stimulation studies for treating thoracic spine pain is probably because of the relatively low incidence rate of thoracic spine disorders. Moreover, the diagnostic difficulty might have partly contributed to the lack of studies on the effectiveness of PRF stimulation in treating pain originating in the thoracic spine. Further studies are, therefore, essential.

Lumbosacral spine disorders

The most common forms of pain associated with lumbosacral spine disorders are radicular, facet joint, and discogenic pain.

Lumbosacral radicular pain

To date, 23 studies have investigated the effects of PRF stimulation of the DRG in patients with lumbosacral radicular pain induced by herniated discs, spinal stenosis, or failed back surgery syndrome (11,15,16,31-50). Of these studies, five were RCTs (15,33,36,42,43), six were prospective observational studies, ten were retrospective studies, and two were case reports. Among the RCTs, Simopoulos *et al*. (43) evaluated the effect of combined CRF and PRF stimulation treatment. Both the PRF stimulation group (37 patients) and the combined treatment group (39 patients) showed a good pain-reduction effect with no difference between the groups. However, the addition of CRF stimulation tended to lengthen the average duration of PRF stimulation analgesic effect from 3.2 to 4.4 months. Shanthanna *et al*. (42) reported relatively small, but better, pain-reduction effect in 14 patients who received the PRF stimulation to the DRG, when compared to the 15 patients who received a placebo intervention. Koh *et al*. (36) found that combination treatment with PRF stimulation and TFESI had better outcomes than did TFESI alone when assessed two and three months after treatment. Lee *et al*. (15) reported that both PRF stimulation of the DRG (9 patients) and TFESI (11 patients) showed significant pain reduction at 2, 4, 8, and 12 weeks after treatment, with similar degrees of pain relief in both treatment groups. Chang *et al*. (33) compared the effects of monopolar and bipolar PRF stimulation of the DRG in 40 patients and showed that bipolar PRF stimulation was more effective than monopolar PRF stimulation in controlling lumbosacral radicular pain.

Six prospective observational studies also showed that PRF stimulation could effectively manage lumbosacral radicular pain (37,39,45,46,49,50). Lee *et al*. (37) performed bipolar PRF stimulation of the DRG in 23 patients whose radicular pain did not respond to the combined treatment of monopolar PRF stimulation and TFESI. The average NRS score changed from 6 to 3.4 at three months after the treatment with bipolar PRF stimulation. Twelve patients (52.2%) reported ≥50% pain reduction.

Ten retrospective studies (11,16,31,35,38,40,41,44,47,48) and two case reports (24,32) have all found that PRF stimulation had a positive effect on lumbosacral pain. Abejón *et al*. (31) reported that radicular pain due to a herniated lumbar disc or spinal stenosis was well-controlled by PRF stimulation. However, patients with failed back surgery syndrome responded poorly to the treatment with PRF stimulation of the DRG. Park and Lee (41) reviewed the treatment outcome of 82 patients with failed back surgery syndrome and found that PRF stimulation of the DRG was only weakly effective in reducing the lumbosacral radicular pain in these patients.

Almost all studies on PRF stimulation for lumbosacral radicular pain showed its usefulness in controlling this pain. The exceptions to this rule are the study by Shanthanna *et al*. (42) and patients with failed back surgery syndrome in the study by Abejón *et al*. (31). Therefore, it can be concluded that PRF stimulation could be beneficial in alleviating lumbosacral radicular pain. However, well-designed RCTs with a sham or a placebo group are warranted to confirm the usefulness of PRF stimulation of the DRG for such pain relief. Additionally, future studies should categorize the cervical spine disorders and adjust for factors affecting the outcomes of the treatment with PRF stimulation.

Lumbosacral facet joint pain

Among the ten studies on lumbosacral facet joint pain (24,51-59), four were RCTs. Tekin *et al*. (59) compared the effects of PRF and CRF stimulation of the lumbar medial branch in 60 patients by dividing them into three equal-sized groups: control, PRF stimulation, and CRF stimulation. Immediately after each procedure, the PRF and CRF stimulation groups showed more pain reduction than did the control group. However, at 6 and 12 months after the treatment procedures, the CRF stimulation group showed a sustained pain-reduction effect, but the PRF stimulation group did not. This study, however, is limited in that the first follow-up was only 6 months after treatment; hence, the effects of PRF stimulation could not have been adequately evaluated. Kroll *et al*. (56) performed PRF or CRF stimulation in two groups of 13 patients each, and found that PRF stimulation of the lumbar medial branches was ineffective in controlling lumbosacral facet joint pain. In contrast, CRF stimulation showed a significant pain reduction at the 3-month post-treatment evaluation. However, their study is limited by the small sample size. Hashemi *et al*. (55) compared the therapeutic effect of PRF stimulation of the lumbar medial branch to that of intra-facet joint corticosteroid injection in 80 patients with degenerative spondylolisthesis. At the 6-week post-treatment evaluation, the effects of both treatments were similar. However, at the 3- and 6-month post-treatment evaluations, the PRF stimulation group showed better pain reduction and functional improvement. Do *et al*. (54) performed an RCT on 60 patients, comparing intra-articular PRF stimulation with intra-facet joint corticosteroid injection. Both procedures successfully controlled facet joint pain, and their positive effect persisted for at least 6 months. At 1 month after the treatment, the corticosteroid injection group showed greater pain reduction. Yet, at 3 and 6 months after the treatment, there were no differences between the groups. Among the four abovementioned RCTs (54-56,59), one study reported about positive therapeutic effects of PRF stimulation of the lumbar medial branches (55) and another when the stimulation was done in the intra-facet joint (54). The other two studies (56,59) did not find any positive effect of PRF stimulation when treating lumbar facet joint pain. However, considering the limitations of these two studies, their utility in determining the effectiveness of PRF stimulation in treating lumbar facet joint pain remains questionable.

Despite the inconsistent results of these four RCTs (54-56,59), the other six studies on a medial branch and intra-articular PRF stimulation [two prospective observational studies (52,53), three retrospective studies (24,51,57), and one case report (58)] showed positive pain reduction and functional improvement during short- or long-term follow-up.

Although the limited number of available studies is insufficient to confirm the effectiveness of PRF stimulation in treating lumbosacral facet joint pain, these studies demonstrate that medial branch or intra-articular PRF stimulation is useful for managing such pain.

Discogenic lower back pain

Discogenic lower back pain is a common form of lower back pain (61). Its primary etiology is abnormal nerve ingrowth and nociceptive pain in the outer annulus fibrosus (61). Although many minimally invasive intradiscal procedures, such as intradiscal electrothermal therapy and CRF ablation, are available, the treatment is still challenging (61). The possibility of using PRF stimulation treatment for discogenic lower back pain has been investigated. PRF stimulation could inhibit the transfer of pain signals from the abnormally growing intradiscal nociceptive nerves. To date, four prospective observational studies (60-63) have reported successful outcomes following intradiscal PRF stimulation treatment, with pain being significantly lower even after one year (60-63).

Despite the positive outcomes in these studies, more RCTs should be performed to support a broader application of PRF stimulation treatment for discogenic back pain. Shortening of the intervertebral disc as an adverse effect of inserting the PRF catheter should also be investigated, for example, by using follow-up magnetic resonance imaging.

Coccydynia

Coccydynia refers to pain in and around the coccygeal region (65-67). Procedures for managing coccydynia include caudal epidural corticosteroid injection, a corticosteroid injection into the intercoccygeal joint, and ganglion impar block with an anesthetic agent and corticosteroids (70). One case report (66) and one retrospective study (67) reported that PRF stimulation of the ganglion impar reduced coccydynia. Gopal *et al*. (66) retrospectively reviewed the data of 20 patients who received PRF stimulation of the ganglion impar to treat coccydynia. Fifteen patients (75%) showed positive treatment effects. Atim *et al*. (65) retrospectively studied the effect of caudal epidural PRF stimulation in 21 patients with coccydynia. Their median NRS score had reduced from 8 before treatment to 2 at the 3-week and 6-month follow-ups.

Nevertheless, no prospective study has investigated the effect of PRF stimulation when used to treat coccydynia, possibly because of its low prevalence. Therefore, further studies are warranted to confirm the therapeutic effectiveness of PRF stimulation for coccydynia.

Conclusions

This review shows that PRF stimulation treatment could be beneficial in controlling pain caused by spinal disorders. None of the 58 reviewed studies reported any serious complications. Moreover, the compelling evidence supports PRF stimulation as an effective treatment for cervical and lumbar radicular and facet joint pain. Nevertheless, to promote a broader application of PRF stimulation as a treatment modality in these spinal disorders, we need more well-designed RCTs that would support the positive therapeutic effects of PRF stimulation. Evidence on the effectiveness of PRF stimulation treatment for pain arising from other spinal disorders, including cervicogenic headache, discogenic neck pain, thoracic facet joint pain, discogenic back pain, and coccydynia, is still lacking, even though some studies have reported positive therapeutic effects. Further well-designed studies are warranted to clarify the application of PRF stimulation treatment for these types of pain disorders. Moreover, studies that would compare the effect of PRF stimulation and analgesic medication have not been conducted. Therefore, researches on this topic are still needed. This is the first review to assess the effectiveness of PRF stimulation with a focus on treating spinal pain. Our review provides insights into the degree of available evidence for each of the spinal pain disorders. This information could help clinicians make informed decisions when considering the use of PRF stimulation for the treatment of various spinal pain conditions.

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Footnote

Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/apm-20-298). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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