Background: Neuropathic pain (NP) is a major public health problem worldwide. Because of the unclear mechanism of NP, its treatment is one of the most difficult medical problems. As a targeted, noninvasive, safe therapy, pulsed radiofrequency (PRF) provides a new method for the treatment of NP; however, its effect on this treatment still lacks support from evidence-based medicine.

Objective: To conduct a meta-analysis of available randomized controlled trials and to evaluate the effectiveness and clinical utility of PRF for the treatment of NP.

Study Design: Meta-analysis.

Setting: All selected studies were randomized controlled trials.

Method: A systematic and comprehensive database search was performed of the PubMed, CENTRAL, EMBASE.com, Cochrane Library, Chinese Biomedical Literature, and Wanfang databases for literature published from the establishment of the databases to December 19, 2015. According to inclusion and exclusion criteria, the results of randomized controlled trials supporting PRF for NP treatment were collected. The risk of bias tool described in the Cochrane Handbook version 5.1.0 was used to assess the quality of each trial. Meta-analysis was performed using RevMan 5.3 software.

Results: A total of 12 randomized controlled trials involving 592 patients met the inclusion criteria. Overall, the results of the meta-analysis showed that, compared with the control group, PRF had a better effect on postherpetic neuralgia (PHN) in terms of pain score (one week, one month, and 3 months), excellent and good rate (one day, one month), and efficiency rate (one day). But PRF did not have a better effect on radicular pain in pain score (3 months). Side effects were less frequently found with the PRF treatment.

Limitations: Although we repeatedly tested the key words and used a manual method to prevent the loss of studies, due to the limitation of the included studies, some of the data were insufficient to complete the meta-analysis, and we were unable to obtain the original data from some studies. Some studies did not report the blind design, which decreased the quality of the current study.

Conclusion: PRF did not have a better effect on radicular pain, and PRF is an effective and safe therapeutic alternative for the analgesia of PHN. However, for a high recurrence rate over a long period, repeated PRF treatment has limitations.

Key words: Neuropathic pain, pulsed radiofrequency, analgesia, meta-analysis

Neuropathic pain (NP) is pain caused by damage or disease affecting the somatosensory nervous system (1). Neuropathic pain is associated with dysesthesia or allodynia. As a common clinical chronic pain, up to 7% to 8% of the European population is affected (2). Therefore, it is very important to find an effective treatment for NP. However, because the mechanisms that underlie the induction and
Eligibility Criteria

Eligibility criteria are detailed in accordance with the PICOS (participants, interventions, controls, outcomes, and studies) framework.

Participants

Participants were participants or patients with NP.

Interventions

Participants or patients with NP had a PRF treatment.

Controls

Traditional treatment (basic drug treatment and nerve block treatment) control conditions were considered.

Outcome

The data pulled from each study included 1) basic information: author, year of publication, published magazines, the number of cases in each group, the proportion of men and women, average age, duration of follow-up time, study design; 2) statistical data: Visual Analogue Scale (VAS), Sleep Interference Score (SIS), Short form of the McGill pain questionnaire (SF-MPQ), dosage of oxycontin (Oxycontin), Excellent and good rate/efficiency rate, Self-Rating Depression Scale (SDS), Self-Rating Anxiety Scale (SAS), Dosage of NAISD (NAISD), the MOS 36-item Short Form health survey (SF-36), Medication Quantification Scale (MQS), Global Perceived Effect (GPE), Oswestry Disability Index (ODI), Numerical Rating Scale (NRS), pain medications, dosage of aspirin (Aspirin). In addition, excellent and good rate was defined as ≥ 50% decrease in pain score (a pain reduction > 50% is often reported in literature as a successful outcome), efficiency rate was defined as ≥ 30% decrease in pain score (> 30% reduction is significant for clinical trials, especially if neuropathic features are taken into account) (20,21).

Studies

RCTs including a comparative study were considered for inclusion.

Search Strategy

A systematic and comprehensive database search was performed of the PubMed, CENTRAL, EMBASE.com, Cochrane library, Chinese Biomedical Literature, and Wanfang databases for literature published from the establishment of the databases to December 19,
2015, with the following search terms in titles and abstracts: neuropathic pain, neurogenic pain, trigeminal neuralgia, dorsal root ganglion, occipital neuralgia, cervicogenic headache, lumbar radicular pain, lumbar-sacral radicular pain, thoracic postherpetic neuralgia and pulsed radiofrequency, pulsed radiofrequency treatment, pulsed radio frequency, and PRF. Filters were used to result in studies with human participants. There was no language limitation.

Eligibility Criteria

Studies were included if they (1) had a RCT design; (2) included patients with NP; (3) used PRF as an intervention; (4) used a traditional treatment such as drugs or nerve block as a control group. Meanwhile, studies were excluded if (1) they used CRF as a control group; (2) subjects were animals; (3) the study reported no data/results.

Study Selection

Two reviewers (Shi and Wu) independently evaluated potentially eligible studies that were identified by our search. Articles were screened for eligibility based on a review of the title and abstract only, and disagreements were resolved by consensus. Of the articles remaining, their full text was accessed and read independently by the initial 2 reviewers. Consensus for inclusion was obtained with the help of a third party, when necessary. In addition, a manual analysis in order to prevent the loss of effective articles was necessary.

Quality Assessment

The internal validity of eligible trials was evaluated in accordance with a set of 7 criteria from the Cochrane Handbook (22): random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and other sources of bias (adequate description of sample size calculation and detailed disclosures of sources of funding). The judgements of bias were expressed as “low risk,” “high risk,” or “unclear risk.” All divergences were resolved by consensus.

Statistical Analysis

For studies with data of sufficient quality and similar in simulation learning and outcome measures, we combined data in a meta-analysis in order to provide a pooled effect estimate. All data were entered into RevMan 5.3 (http://tech.cochrane.org/revman/download), where standardized deviations and 95% confidence intervals (CIs) were calculated and pooled. The results were expressed as weighted mean difference (MD) with 95% CI for continuous outcomes and as an odds ratio (OR) with a 95% CI for dichotomous variables.

For each analysis, a heterogeneity test was performed using I2 statistics, which measures the extent of inconsistency among results and is interpreted approximately as the proportion of total variation across studies attributable to heterogeneity and not to chance. I2 = 25% was considered low, 50% moderate, and 75% high (22). I2 values higher than 50% were considered as having substantial heterogeneity, and the random-effects model was therefore applied for analysis of the data (22). In addition, we performed subgroup analysis according to prespecified variables, including study design and intervention characteristics (i.e., age, gender, test design, and test time). If there had been no statistical heterogeneity, we would have used a fixed-effect model. Subsequently, we performed subgroup analyses according to the study design. Design was chosen as a potential moderator because different designs were included in the meta-analysis and we considered it important to analyze by subgroup. To test for publication bias, a funnel plot, which graphs the effect size of each study according to its respective size effect (SE), was used. We assumed the existence of publication bias if there were no small studies with effect sizes favoring control groups. A two-tailed P-value of less than 0.05 was considered significant (22).

Results

Study Selection

The electronic database search of the PubMed, CENTRAL, EMBASE.com, Cochrane library, Chinese Biomedical Literature, and Wanfang databases provided a total of 2,870 citations, and 66 citations were found manually. After removing duplicate manuscripts, 2,778 studies remained. Of these, 2,548 were excluded based on the title and abstract review, leaving 230 for full-text review. These 230 studies with their full text were retrieved and reviewed for eligibility, and 189 were excluded based on study design and outcome measures. This resulted in 41 studies that met all the criteria, and these were selected for inclusion. After being reviewed, a total of 12 articles were included in the final analysis (21,23-33) (Fig. 1).
Study Characteristics

The selected studies included 592 cases, 304 cases in the treatment group and 288 cases in the control group, with 287 men and 305 women. The study duration ranged from 3 months to 6 years, and the follow-up time was more than 3 months. Table I shows the basic characteristics of the included studies.
## Treatment of Neuropathic Pain Using Pulsed Radiofrequency

### Quality Assessment

Based on the Cochrane Handbook 5.1 Assessment Tool, Figs. 2 and 3 show the risk of bias among studies, which were judged by the 7 criteria. Results showed that most of the trials had reported a random design method but few reported an allocation concealment scheme; some of the trials reported a detailed blind design.

### Meta-analysis Results

#### Pain Score Analysis

1. Comparing PRF with the control group, a total of 3 articles reported changes in pain score after one week. Figure 4 shows that there is a low heterogeneity between the trials after one week (Chi2 = 3.78, I2 = 47%).

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Table I. **Basic characteristics of the included studies.**

<table>
<thead>
<tr>
<th>Study</th>
<th>A1</th>
<th>B2</th>
<th>Gender1</th>
<th>Gender2</th>
<th>Age1</th>
<th>Age2</th>
<th>Disease</th>
<th>T/C</th>
<th>Duration</th>
<th>Lost</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>You et al, 2011</td>
<td>30</td>
<td>18</td>
<td>16/14</td>
<td>10/8</td>
<td>≥ 50 ± 28</td>
<td>≥ 50 ± 17</td>
<td>PHN</td>
<td>PRF/NB</td>
<td>1 y</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Liu et al, 2014</td>
<td>40</td>
<td>37</td>
<td>16/24</td>
<td>17/20</td>
<td>70 ± 16</td>
<td>64 ± 15</td>
<td>PHN</td>
<td>PRF/BD</td>
<td>6 m – 3 y</td>
<td>3</td>
<td>1/2/3</td>
</tr>
<tr>
<td>Huang et al, 2012</td>
<td>30</td>
<td>30</td>
<td>37/23</td>
<td>64.3 ± 13.1</td>
<td>PHN</td>
<td>PRF/BD</td>
<td>4 m – 6 y</td>
<td>0</td>
<td>1/4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deng et al, 2013</td>
<td>30</td>
<td>30</td>
<td>14/16</td>
<td>13/17</td>
<td>PHN</td>
<td>PRF/NB</td>
<td>3 m</td>
<td>0</td>
<td>1/5/6/7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ke et al, 2013</td>
<td>48</td>
<td>48</td>
<td>25/23</td>
<td>22/26</td>
<td>73.04 ± 6.5</td>
<td>71.14 ± 7.2</td>
<td>PHN</td>
<td>PRF/BD</td>
<td>6 m</td>
<td>4</td>
<td>1/8/9</td>
</tr>
<tr>
<td>Gabrhelik et al, 2011</td>
<td>15</td>
<td>15</td>
<td>6/9</td>
<td>7/8</td>
<td>43.6 ± 9.2</td>
<td>45.9 ± 12.8</td>
<td>CH</td>
<td>PRF/NB</td>
<td>9 m</td>
<td>0</td>
<td>1/10/11</td>
</tr>
<tr>
<td>Shanthanna et al, 2014</td>
<td>16</td>
<td>15</td>
<td>10/6</td>
<td>8/7</td>
<td>62 (45 – 85)</td>
<td>57 (35 – 83)</td>
<td>LRP</td>
<td>PRF/BD</td>
<td>15 m</td>
<td>2</td>
<td>1/12</td>
</tr>
<tr>
<td>Fujii et al, 2012</td>
<td>16</td>
<td>11</td>
<td>9/7</td>
<td>6/5</td>
<td>66.6 ± 18.2</td>
<td>67.4 ± 10.9</td>
<td>LSRP</td>
<td>PRF/NB</td>
<td>1 y</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Koh et al, 2014</td>
<td>31</td>
<td>31</td>
<td>11/20</td>
<td>10/21</td>
<td>65.97 ± 7.2</td>
<td>66.16 ± 8.9</td>
<td>LRP</td>
<td>PRF/NB</td>
<td>3 m</td>
<td>0</td>
<td>10/11/12/13</td>
</tr>
<tr>
<td>Zundert et al, 2007</td>
<td>11</td>
<td>12</td>
<td>5/6</td>
<td>5/7</td>
<td>42 ± 12.2</td>
<td>52.9 ± 11.9</td>
<td>CRP</td>
<td>PRF/NB</td>
<td>9 m</td>
<td>0</td>
<td>1/9/11/14</td>
</tr>
<tr>
<td>Yang et al, 2015</td>
<td>15</td>
<td>15</td>
<td>4/11</td>
<td>3/12</td>
<td>43.5 ± 10.6</td>
<td>39.2 ± 9.3</td>
<td>CH</td>
<td>PRF/BD</td>
<td>2 y</td>
<td>0</td>
<td>1/15</td>
</tr>
<tr>
<td>Zhang et al, 2015</td>
<td>22</td>
<td>26</td>
<td>15/7</td>
<td>18/8</td>
<td>65 ± 18</td>
<td>61 ± 18</td>
<td>LRP</td>
<td>PRF/BD</td>
<td>3 y</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>


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Fig. 2. Quality evaluation of summary of included studies.
Therefore the fixed-effect model was used. PRF showed significant treatment effects on the pain score [MD = -0.78, 95%CI (-1.09, -0.47), \( P < 0.00001 \)], but caution should be exercised while drawing conclusions. The results showed that compared with the control group, PRF had a better analgesic effect. As a rule of thumb, tests for funnel plot asymmetry should only be used when there are at least 10 studies included in the meta-analysis, so we did not have a test for funnel plot asymmetry in this analysis.

2. Comparing PRF with the control group, a total of 4 articles reported changes in pain score after one month.

Figure 5 shows that there is a low heterogeneity between the trials after one month (Chi2 = 4.45, I2 = 33%). Therefore the fixed-effect model was used. PRF showed significant treatment effects on the pain score [MD = -0.87, 95%CI (-1.19, -0.55), \( P < 0.00001 \)], but caution should be exercised while drawing conclusions. The results showed that compared with the control group, PRF had a better analgesic effect. As a rule of thumb, tests for funnel plot asymmetry should only be used when there are at least 10 studies included in the meta-analysis, so we did not have a test for funnel plot asymmetry in this analysis.

3. Comparing PRF with the control group, a total of 4 articles reported changes in pain score after 3 months.

Figure 6 shows that there is a high heterogeneity between the trials after 3 months (Chi2 = 13.21, I2 = 62%).
Therefore the random-effect model was used. PRF showed significant treatment effects on the pain score \( \text{MD} = -0.66, 95\% \text{CI} (-1.12, -0.20), P = 0.005 \), but caution should be exercised while drawing conclusions. The results showed that compared with the control group, PRF had a better analgesic effect. Subgroup analyses were conducted based on the different NP diagnoses (PHN and radicular pain). In subgroup analyses, 2 studies involving 137 participants with a PHN diagnosis tended to have significant effects on pain score \( \text{MD} = -1.26, 95\% \text{CI} (-1.69, -0.84), P < 0.00001 \), indicating some heterogeneity between the different NP diagnoses \( I^2 = 0\% \). In addition, the heterogeneity was significantly low in subgroup analyses (Fig. 7). As a rule of thumb, tests for funnel plot asymmetry should only be used when there are at least 10 studies included in the meta-analysis, so we did not have a test for funnel plot asymmetry in this analysis. The results suggested that the excellent and good rates of PRF are higher than those of the traditional treatments.

2. Comparing PRF with the control group, a total of 3 articles reported excellent and good rates after one month.

Figure 8 shows that there is a low heterogeneity between the trials after one day \( \text{Chi}^2 = 0.10, I^2 = 0\% \). Therefore the fixed-effect model was used. PRF showed significant treatment effects on the excellent and good rate \( \text{OR} = 3.35, 95\% \text{CI} (1.49, 7.51), P < 0.003 \), but caution should be exercised while drawing conclusions. As a rule of thumb, tests for funnel plot asymmetry should only be used when there are at least 10 studies included in the meta-analysis, so we did not have a test for funnel plot asymmetry in this analysis.

Figure 9 shows that there is a low heterogeneity between the trials after one month \( \text{Chi}^2 = 2.62, I^2 = 24\% \). Therefore the fixed-effect model was used. PRF showed significant treatment effects on the excellent and good rates \( \text{OR} = 3.32, 95\% \text{CI} (1.42, 7.73), P = 0.005 \), but caution should be exercised while drawing conclusions. As a rule of thumb, tests for funnel plot asymmetry should only be used when there are at least 10 studies included in the meta-analysis, so we did not
have a test for funnel plot asymmetry in this analysis. The results suggested that the excellent and good rates of PRF are higher than those of the traditional treatments.

3. Comparing PRF with the control group, a total of 2 articles reported an efficiency rate after one day. Figure 10 shows that there is a low heterogeneity between the trials after one day (Chi² = 0.04, I² = 0%). Therefore the fixed-effect model was used. PRF showed significant treatment effects on the efficiency rate [OR = 7.78, 95%CI (2.38, 25.45), P = 0.0007], but caution should be exercised while drawing conclusions. As a rule of thumb, tests for funnel plot asymmetry
should only be used when there are at least 10 studies included in the meta-analysis, so we did not have a test for funnel plot asymmetry in this analysis. The results suggested that the efficiency rates of PRF are higher than those of the traditional treatments.

**Other Data**

Due to the limitation of the included studies, some of the data were insufficient to complete the meta-analysis (n < 2), and for others the original data could not be obtained. We show the unanalyzed data here. All the studies were reported in A (PRF) and B (control) (Tables II – XII).

1. Table 2 shows that in Deng et al’s study (26), PRF showed significant treatment effects on the pain score (2 weeks), excellent and good rate (one week, 2 weeks), efficiency rate (one week, 2 weeks), SDS (one day, one week, 2 weeks, one month), and SAS (one day, one week, 2 weeks, one month) (P < 0.05).

2. Table 3 shows that in Liu et al’s study (24), PRF showed significant treatment effects on the SIS score (one day, one week, one month, 3 months) and SF-MPQ (one day, one week, one month, 3 months) (P < 0.05).

3. Table 4 shows that in Huang et al’s study (25), PRF showed significant treatment effects on dosage of oxycontin (one day, one week, one month, 3 months, 6 months) (P < 0.05).

4. Table 5 shows that in Gabrhelík et al’s study (28), PRF showed significant treatment effects on the pain score (3 months, 9 months) and MQS (3 months, 9 months) (P < 0.05), but there were no statistically significant differences in the GPE (P = 0.272).

5. Table 6 shows that in Shanthanna et al’s study (30), there were no statistically significant differences...
between PRF and the control group on the pain score or ODI (P > 0.05).

6. Table 7 shows that in Koh et al’s study (21), there were no statistically significant differences between PRF and the control group on the excellent and good rate (2 months), efficiency rate (2 months, 3 months), 30% decrease in ODI (one month, 2 months, 3 months), increase in ODI (one month, 2 months, 3 months), 25% decrease in MQS (one month, 2 months, 3 months), increase in MQS (one month, 2 months, 3 months), ≥ 6 points on GPE scale (one month, 2 months, 3 months), ODI (3 months), pain score (A–B) (3 months), ODI (A–B) (3 months), and MQS (A–B) (3 months) (P > 0.05); PRF showed significant treatment effects on the ODI (one month, 2 months) (P < 0.05).

7. Table 8 shows that in Ke et al’s study (27), PRF showed significant treatment effects on the pain score (3 days, one week, 2 weeks, one month, 2 months, 6 months), dosage (one day, 3 days, one week, 2 weeks, one month), and SF-36 (one month, 2 months, 3 months, 6 months) (P < 0.05).

8. Table IX shows that in Fujii et al’s study (31), PRF showed significant treatment effects on the pain score (one day, one week) (P < 0.05); the control
Table 7. The unanalyzed data of Koh et al’s study.

<table>
<thead>
<tr>
<th>Koh et al</th>
<th>1 month</th>
<th>2 months</th>
<th>3 months</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A/B</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>excellent and good rate</td>
<td>6/31 (19.4%)</td>
<td>4/31 (12.9%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>efficiency rate</td>
<td>16/31 (51.6%)</td>
<td>13/31 (41.9%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30% decrease in ODI</td>
<td>14/31 (45.2%)</td>
<td>11/31 (35.5%)</td>
<td>8/31 (25.8%)</td>
<td></td>
</tr>
<tr>
<td>increase in ODI</td>
<td>4/31 (12.9%)</td>
<td>3/31 (9.7%)</td>
<td>3/31 (9.7%)</td>
<td></td>
</tr>
<tr>
<td>25% decrease in MQS</td>
<td>0</td>
<td>1/31 (3.2%)</td>
<td>6/31 (19.4%)</td>
<td></td>
</tr>
<tr>
<td>increase in MQS</td>
<td>0</td>
<td>1/31 (3.2%)</td>
<td>4/31 (12.9%)</td>
<td></td>
</tr>
<tr>
<td>≥ 6 points on GPE scale</td>
<td>14/31 (45.2%)</td>
<td>7/31 (22.6%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ODI</td>
<td>35.36 (30.58 – 40.14)</td>
<td>35.07 (30.24 – 39.90)</td>
<td>37.62 (32.67 – 42.57)</td>
<td>*P &gt; 0.05 A/B</td>
</tr>
<tr>
<td>Pain score (A-B) 3 month</td>
<td>34.06 (28.33 – 39.79)</td>
<td>36.48 (30.76 – 42.21)</td>
<td>37.99 (32.53 – 43.44)*</td>
<td></td>
</tr>
<tr>
<td>Pain score (A-baseline) 3 month</td>
<td>0.331 (−0.252 to 0.914)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ODI (A-B) 3 month</td>
<td>−0.813 (−1.579 – −0.046)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ODI (A-baseline) 3 month</td>
<td>2.134 (−4.316 to 8.584)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MQS (A-B) 3 month</td>
<td>−3.655 (−9.585 – 2.276)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MQS (A-baseline) 3 month</td>
<td>0.536 (−1.927 to 2.999)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ODI: Oswestry Disability Index; MQS: Medication quantification scale

The unanalyzed data of Koh et al’s study showed significant treatment effects on the pain score (3 months, 6 months, 12 months) (P < 0.05); there were no statistically significant differences between PRF and the control group on the pain score (one month) (P > 0.05).

9. Table 10 shows that in Van Zundert et al’s study (29), there were no statistically significant differences between PRF and the control group on the pain medication (3 months) and SF-36 (3 months); PRF showed significant treatment effects on the GPE (one month, 3 months, 6 months) (P < 0.05).

10. Table 11 shows that in Yang et al’s study (32), PRF showed significant treatment effects on dosage of aspirin (one month, 2 months, 6 months) (P < 0.05).

**Side Effects and Complications**

Table 12 shows the side effects and complications of the included studies.

**Discussion**

NP is a result of a primary lesion or dysfunction of the peripheral or central nervous system. A range of disorders of the peripheral nervous system—such as postherpetic neuralgia, trigeminal neuralgia, lumbar radicular pain, lumbosacral radicular pain, and cervical radicular pain—and a series of neuropathies are included under the term. Its prominent symptoms in patients are allodynia and hyperalgesia (3). As mechanisms of NP are unknown, its treatment is challenging. Analgesics, nonsteroidal anti-inflammatory drugs, physical therapy/rehabilitation, and a surgical approach can be used to address this issue (34). However, the evidence regarding the efficiency of these treatments and their superiority over one another is limited (6). The long duration of NP seriously influences patients’ quality of life and causes them a huge economic burden.

RF procedures are an important part of complex, minimally invasive treatments for chronic pain condi-
tions and are used for reducing noxious transmission in the nervous system. PRF is a pain treatment modality used to manage pain in clinical practice; it has been associated with several advantages, including improved safety, easy application, and fewer side effects than CRF (4). The mechanism of PRF is yet to be elucidated. Results of experiments involving animals have suggested that PRF may change the expression of c-fos in laminae I and II of the dorsal horn (35,36). Mikeladze et al (17) showed that PRF appeared to interrupt signals only in unmyelinated C fibers while leaving myelinated delta fibers functional to transmit pain signals. PRF is considered to induce an electric field in the regions of the dorsal root ganglion and influence local neuronal function (8). The results of previous experiments collectively suggested that PRF appeared to provide neuromodulation in response to painful stimuli without changing the morphology of motor and sensitive fibers; it probably works with a temperature independent pathway mediated by changing electric fields (37).

Since PRF does not produce sufficient heat around the probe or the tissue to damage nerves, there is no risk of deafferentation pain. A large number of studies have shown that PRF has an analgesic effect in the

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Table 8. The unanalyzed data of Ke et al’s study.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>3 days</th>
<th>1 week</th>
<th>2 weeks</th>
<th>1 month</th>
<th>2 months</th>
<th>6 months</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAS A &lt; B</td>
<td>A &lt; B</td>
<td>A &lt; B</td>
<td>A &lt; B</td>
<td>A &lt; B</td>
<td>A &lt; B</td>
<td>A &lt; B</td>
<td>( P &lt; 0.001 )</td>
</tr>
<tr>
<td>Dosage</td>
<td>A &lt; B</td>
<td>3 days</td>
<td>1 week</td>
<td>2 weeks</td>
<td>1 month</td>
<td>( P ) value</td>
<td></td>
</tr>
<tr>
<td>SF-36</td>
<td>1 month</td>
<td>2 months</td>
<td>3 months</td>
<td>6 months</td>
<td>( P ) value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A &gt; B</td>
<td>A &gt; B</td>
<td>A &gt; B</td>
<td>A &gt; B</td>
<td>( P &lt; 0.05 )</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SF-36: the MOS 36-item short from health survey

Table 9. The unanalyzed data of Fujii et al’s study.

<table>
<thead>
<tr>
<th>Time</th>
<th>1 day</th>
<th>1 week</th>
<th>1 month</th>
<th>3 months</th>
<th>6 months</th>
<th>12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status</td>
<td>A &lt; B</td>
<td>A &lt; B</td>
<td>A &gt; B</td>
<td>A &gt; B</td>
<td>A &gt; B</td>
<td>( P ) value</td>
</tr>
<tr>
<td>( P )</td>
<td>( P &lt; 0.05 )</td>
<td>( P &lt; 0.05 )</td>
<td>( P &gt; 0.05 )</td>
<td>( P &lt; 0.05 )</td>
<td>( P &lt; 0.05 )</td>
<td>( P &lt; 0.05 )</td>
</tr>
</tbody>
</table>

Table 10. The unanalyzed data of Zundert et al’s study.

<table>
<thead>
<tr>
<th>Zundert et al</th>
<th>Higher</th>
<th>Equal</th>
<th>Lower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain medication (3 months)</td>
<td>1/11</td>
<td>4/11</td>
<td>6/11</td>
</tr>
<tr>
<td></td>
<td>5/12</td>
<td>3/12</td>
<td>4/11</td>
</tr>
<tr>
<td>1 month</td>
<td>3 months</td>
<td>6 months</td>
<td></td>
</tr>
<tr>
<td>Status</td>
<td>7/11</td>
<td>9/11</td>
<td>7/11</td>
</tr>
<tr>
<td></td>
<td>5/12</td>
<td>4/12</td>
<td>2/12</td>
</tr>
<tr>
<td>SF-36</td>
<td>1 month</td>
<td>3 months</td>
<td>6 months</td>
</tr>
<tr>
<td></td>
<td>A &gt; B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( P )</td>
<td>( &lt; 0.05 )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GPE: Global Perceived Effect; SF-36: the MOS 36-item short from health survey

Table 11. The unanalyzed data of Zhang et al’s study.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>1 month</th>
<th>2 months</th>
<th>6 months</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspirin</td>
<td>3.93 ± 1.9</td>
<td>3.40 ± 1.54</td>
<td>3.73 ± 1.33</td>
<td>( P &lt; 0.05 )</td>
</tr>
<tr>
<td>A/B</td>
<td>5.40 ± 1.92</td>
<td>5.40 ± 1.8</td>
<td>6.13 ± 1.88</td>
<td></td>
</tr>
</tbody>
</table>
Treatment of Neuropathic Pain Using Pulsed Radiofrequency

Ren (38) reported a > 50% remission in 80% of patients after PRF treatment, suggesting that PRF has a good treatment effect for NP. Shabat et al (7) explained that 86% of patients reported an improvement in pain after one month, while 2 patients remained pain free, 7 patients had good results, and 11 patients had moderate results after 6 months. However, there is a lack of meta-analysis regarding the effectiveness and clinical utility of PRF for the treatment of NP.

In this study, a meta-analysis was conducted including 12 studies. The following outcomes were measured: (1) pain score (2) excellent and good rate/efficiency rate.

**PHN**

The results of pain scores and excellent and good rate/efficiency rate suggested that PRF appeared to have beneficial effects on PHN relief after one week, one month, and 3 months (P < 0.05). The current results suggest that PRF might work better in sensory conduction, which has a better analgesic effect on PHN patients. In addition, PRF showed significant treatment effects on the pain score in 3 months, which suggested that for the treatment of NP, PRF has a better analgesia duration on PHN; it is very important for reducing the economic burden of patients and reducing the dose of analgesic drugs, and it improves patients’ quality of life. Our results also support the results of previous studies, such as those of Kim et al (39), who reported that in 59 cases of PHN, there was excellent pain relief (about 55%) at 4 weeks after PRF, and of a prospective study of occipital neuralgia by Vanelderen et al (40), who reported a decreased VAS with PRF treatment. In a word, PRF has a good analgesic effect for the treatment of PHN over a short time, and its analgesic effect is much better than traditional treatment (8).

Due to the limitation of the included studies, the data of some studies were insufficient to complete the meta-analysis (n < 2), and the original data could not be obtained for others studies. By observing data, most of the included studies showed that PRF had a better significant treatment effect than traditional treatments, just like our meta-analysis results.

**Radicular Pain**

The results of pain scores showed no statistically significant differences between the PRF and control groups in subgroup analysis (3 months) (P > 0.05). The results suggested that PRF was not associated with significantly better therapeutic effects on radicular pain, and that PRF was associated with effects similar to those of traditional treatments. This conclusion was also supported by other studies. For example, Shanthanna et al (30) reported no significant differences in VAS scores and ODIs between the PRF and control groups. Additionally, Koh et al (21) reported no statistically significant differences in VAS scores and ODIs between the PRF and control groups. Furthermore, Van Zundert et al (29) reported no statistically significant differences between the PRF and control groups on the pain medication and SF-36 scores. Collectively, the aforementioned results

<table>
<thead>
<tr>
<th>Study</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liu et al</td>
<td>Liu et al reported that in the control group, 4 participants had a local swelling, symptoms resolved after 1 – 3 days; in the treatment group, 5 participants had a local swelling, symptoms resolved after 1 – 3 days, and 6 participants had a slightly decreased innervation feeling, symptoms resolved after 1 – 3 weeks.</td>
</tr>
<tr>
<td>Gabrhelík et al</td>
<td>Gabrhelík et al reported that 3 patients (10%) had pain at the injection site for longer than one day.</td>
</tr>
<tr>
<td>Shanthanna et al</td>
<td>Shanthanna et al reported that 2 patients in each group had a headache and a transient increase in back pain, which did not last beyond one day.</td>
</tr>
<tr>
<td>Koh et al</td>
<td>Koh et al reported that several patients reported temporary pain during needle insertion and paresthesia during sensory stimulation, which was tolerable and did not require additional medications or discontinuation of the procedure. Six patients in the PRF group and 4 patients in the control group complained of pain aggravation that presented for 2 – 3 days, but spontaneous relief occurred without any sequelae.</td>
</tr>
<tr>
<td>Ke et al</td>
<td>Ke et al reported that bradycardia was found in one patient from the PRF group. This patient’s heart rate fell to 45 beats per minute, and returned to 60 to 70 beats per minute when the PRF was stopped.</td>
</tr>
<tr>
<td>Summary</td>
<td>The included studies did not report any serious side effects or complications related to the treatment. Pain, paresthesia, or subcutaneous hematoma at the injection site may happen during the PRF. There might be an increased low back pain or headache after the PRF after a short time. Very few people would suffer a pneumothorax or bradycardia.</td>
</tr>
</tbody>
</table>
suggested that PRF was not associated with significantly better therapeutic effects on radicular pain, and that PRF was associated with effects similar to those of traditional treatments. Compared with the traditional methods, PRF had no special effects in radicular pain. Despite this, the simple and facile characteristics of PRF were associated with advantages over long-term drug treatments.

Other Data

It is also noteworthy that Makharita and Amr (41) found more robust and significant treatment effects in the control group as compared with the PRF group during 4 to 12 months of the treatment. Additionally, Fujii et al (31) reported that from 3 to 12 months, the control group tended to demonstrate better pain relief. The aforementioned results indicated that PRF may not have a significant treatment effect on NP in the long term, suggesting that PRF has a limited duration of efficacy. Because the effects of PRF were observed to wear off, repeated treatments may be required to ensure a continuous analgesic effect. This assertion has been supported by the results of other studies, such as that of Boxem et al (42), reporting that pain remission in those receiving PRF treatment lasted for only 9.89 months in patients with lumbosacral radicular pain. That experimental result showed that PRF had a limited duration of efficacy and therefore required repeated treatments. It also provided a reference for physicians who need to make decisions regarding the choice of treatment options.

In brief, PRF has different effects depending on the types of NP, and PRF treatment may require repeated administrations over longer durations. It is also an effective and safe short-term therapeutic alternative for the treatment of PHN; however, repeated PRF treatments have been associated with limitations for those with high recurrence rates over long durations.

Side Effects and Complications

Our results showed that the included studies did not report any serious side effects or complications related to the treatment. A pain, paresthesia, or subcutaneous hematoma often appeared at the injection site. It seemed that PRF is a safe therapeutic alternative for the treatment of NP.

Quality Assessment Scoring

Our results suggest that most of the papers on PHN studies have higher literature quality than those on radicular pain studies. It is well known that radicular pain is associated with compression of the peripheral nerves including motor and sensory nerves. However varying extent of compression would typically lead to significantly varying senses among individual patients with radicular pain, contributing to high heterogeneity of the studies. In contrast, as PHN is simply caused by the herpes zoster virus, the patients would have similar symptoms and intensity of pain, contributing to low heterogeneity and hence higher quality of the relevant studies. These may be the primary reasons for the difference in the literature quality scores for the 2 types of pain.

Limitations

Although we repeatedly tested the key words and used a manual method to prevent the loss of studies, due to the limitation of the included studies, some of the data were insufficient to complete the meta-analysis, and we were unable to obtain the original data for some studies; 2. Some studies did not report the random and blind design, which decreased the quality of the current study. Therefore, large-scale, multiple-term, high-quality RCTs would be necessary to prove or disprove the significant advantages or disadvantages.

Conclusion

PRF did not have a better effect on radicular pain, and PRF is an effective and safe therapeutic alternative for the analgesia of PHN. However, for a high recurrence rate over a long period, repeated PRF treatment has limitations.
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References


31. Fujii H, Kosogabe Y, Kajiki H. [Long-


