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Pulsed radiofrequency in clinical practice – A retrospective analysis of 238 patients with chronic non-cancer pain treated at an academic tertiary pain centre

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HIGHLIGHTS

- Pulsed radiofrequency (PRF) is a non-neurodestructive invasive pain treatment method.
- The clinical effect of a broad use of PRF was analysed in 238 patients.
- 30% experienced major improvement when treated for suspected facetogenic lumbago.
- Treatment niches for pulsed radiofrequency need to be defined in future studies.

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ABSTRACT

Background and aims: Pulsed radiofrequency is a non-neurodestructive invasive pain treatment which, in contrast to conventional continuous radiofrequency treatment, does not entail nerve tissue destruction. The aim of this study was to retrospectively analyse the short-term benefits of a broad use of pulsed radiofrequency in clinical practice.

Methods: The medical records of all patients treated with pulsed radiofrequency, or who received a diagnostic test block with a local anaesthetic in view of such a treatment, were retrospectively analysed. The patients had been referred to a tertiary pain centre in Sweden. The treatment effect one month after pulsed radiofrequency was retrospectively graded as follows, based on the wordings of the medical records: major improvement; minor improvement; no change; or worsened.

Results: A total of 238 patients received 587 interventions from 2009 to 2014. Chronic low back pain (CLBP) was by far the most common treatment indication (57% of patients), followed by CLBP with sciatica (9%). The age at first pulsed radiofrequency was 55 (15–94) years (mean, range), and 65% were female. Thirty-six patients (15%) underwent only a diagnostic test block using a local anaesthetic, i.e., the test block did not lead to treatment with pulsed radiofrequency. A total of 445 pulsed radiofrequency interventions were performed on 202 patients.

Dichotomizing data into responders (i.e., minor or major improvement) and non-responders (i.e., worsened or no change), we found that, out of 63 responders to a median branch diagnostic test block (either at the cervical or lumbar level), 33 were responders to the first following median branch pulsed radiofrequency. Hence the positive predictive value of a median branch test block was 52%.

In 127 patients, the lumbar level was targeted for median branch pulsed radiofrequency because of clinically suspected lumbar facetogenic pain. Looking at the first treatment, 30% experienced major improvement after 1 month, 16% minor improvement, 36% no change, 5% a worsened situation, and the effect was not assessable in 13% of patients. Lone dorsal root ganglion L2-treatment for suspected discogenic lumbar pain was done on 39 patients and, after one month, the effect was not assessable in 17% of patients, 14% had major improvement, 14% minor improvement, and 55% had no change.

In 40 patients, a dorsal root ganglion or a peripheral nerve was targeted because of a non-axial chronic pain condition. There was a plethora of indications, but the most common was by far related to some form of neuropathic pain (52% of interventions, mainly because of neuralgia), followed by chronic nociceptive shoulder pain (8% of interventions).

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Conclusions: This study shows that, after one month, the effect size of a broad and indiscriminate clinical use of pulsed radiofrequency is rather small.
Implications: The clinical effectiveness of pulsed radiofrequency has to be investigated further in carefully selected and more homogenous patient groups, in order to define effective treatment niches for this nondestructive invasive treatment method.

1. Introduction

Pulsed radiofrequency (PRF) is a non-neurodestructive invasive pain treatment [1]. Compared to conventional continuous radiofrequency treatment (CRF), PRF offers the advantage of pain control without tissue destruction. In CRF, a high frequency alternating current is applied in the vicinity of a nerve, leading to neurodestructive thermocoagulation. In contrast, PRF entails short current bursts followed by silent phases, leading to heat dissemination and therefore to non-neurodestructive effects [2,3]. The analgesic effect of PRF is somewhat difficult to explain, but animal data suggest that PRF has neuromodulatory effects [1,2]. For instance, in an animal neuropathic pain model, PRF has been shown to modulate the expression of pain genes at several sites along the nociceptive pathways [4]. In the specific case of radicular pain, it is thought that the rather strong electromagnetic field generated by PRF around the electrode tip potentially disrupts the pathophysiological processes in the dorsal root ganglion (DRG) and/or centrally; however, the precise way in which PRF interacts with afferent nociceptive signalling remains unclear [5].

CRF is frequently used to treat facetogenic back pain, i.e., pain that is thought to be caused by the facet joints. It is thought that repetitive stress and/or cumulative low-level trauma can lead to facet joint inflammation and subsequent pain generation [6]. Nociception from a facet joint can be interrupted by lesioning the medial branches of the posterior primary rami above and below the joint [7]. However, other structures can also generate back pain, e.g. the intervertebral discs, the sacroiliac joint, or myofascial structures [6,8]. Concerning the treatment of facet joint pain, the evidence favours CRF over PRF [1]. However, the neurodestructive nature of CRF is a drawback, prompting some interventional pain physicians to use PRF instead.

In an analysis of randomised controlled trials (RCTs) of radiofrequency treatment for chronic low back pain (CLBP), the authors of a recent Cochrane systematic review [9] concluded that the available evidence is of poor quality. Short term, there is moderate evidence that CRF has a greater pain-reducing effect than placebo in facetogenic CLBP. When comparing facet joint CRF with steroid injections, there is evidence of very low to low quality showing that facet joint CRF provides better pain reduction both short and long term. Overall, the review concluded that high quality RCTs with larger patient samples are needed, as are data on long-term effects [9].

Concerning the treatment of radicular pain, CRF on the DRG is not recommended, but PRF might be a possible option [10]. PRF on peripheral nerves (PN) has also been described, either as treatment of neuropathic pain [11] or as treatment of a well-localized nociceptive pain, e.g. PRF of the suprascapular nerve because of chronic shoulder pain [12].

At our clinical department, PRF is preferred over CRF for chronic non-cancer pain. This paper was a quality improvement project in real-life patients. The aim was to retrospectively and self-critically analyse the short-term benefit of a broad use of PRF in clinical practice.

2. Material and methods

2.1. Patients and retrospective analysis

The medical records of all patients treated with PRF, or who received a diagnostic test block with a local anaesthetic in view of PRF, during the period 2009–2014 were retrospectively analysed. The patients had been referred to a tertiary pain centre in Sweden. Approximately one month after PRF, the treatment effect was retrospectively and clinically graded as follows, based on the wordings of the medical records: major improvement; minor improvement; no change; or worsened. Wordings like “at least 50% pain relief”, “very much better”, “substantially less pain”, and the like, were considered as major improvement. Expressions like “somewhat better”, “some effect”, or “amelioration”, and the like, were graded as minor improvement. Instances like “only marginal improvement” or “uncertain” were equated with no change. Sometimes, the wordings were equivocal and no conclusion could be reached, rendering a verdict of “not assessable”.

2.2. Clinical assessment of low back pain patients

The clinical assessment of patients with unspecific CLBP is difficult, potential pain generators being e.g., the intervertebral discs (discogenic pain), facet joints (facetogenic pain or “facet syndrome”), the sacroiliac joint, or myofascial structures [6,8]. Generally speaking, the combination of unilateral localized back pain without radiculopathy, pain on movement, and paravertebral pressure pain appears to support the diagnosis of facetogenic pain, but it is important to acknowledge that no physical examination findings are pathognomonic for this condition [6]. Radiological finding did only play a minor role in the overall clinical workup. Clinical suspicion of facetogenic pain warranted a median branch PRF (MB-PRF), often preceded by a corresponding diagnostic test block using 0.5 ml of lidocaine 10 mg/ml without corticosteroids. The effect of the test block was clinically evaluated by a follow-up telephone call. For the purpose of the present study, the effect of the test block was retrospectively graded as described above according to the wordings of the medical records.

2.3. Pulsed radiofrequency treatment

Patients were treated with PRF using NeuroTherm® NT1100 (St. Jude Medical, St. Paul, MN, USA), with or without a previous diagnostic test block with a local anaesthetic. The technique used for the cervical, thoracic and lumbar regions was *ad modum* Sluijter [7] with a 20 or 22 Gauge OWL insulated radiofrequency needle (Diros Technology Inc., Markham, Ontario, Canada) and c-arm fluoroscopy (or sometimes ultrasound for peripheral nerves). Sensory stimulation at 50 Hz was effectuated, and a sensory threshold of 0.5 V was considered appropriate in order to confirm correct needle placement. Motor stimulation at 2 Hz was also effectuated as appropriate. The patients were then treated with PRF at 42 °C for 120 s (at 40 V, 2 Hz, and pulse duration 20 ms), provided the impedance

was <500 Ω; if needed, the impedance was lowered by injection 0.5–1 ml of normal saline [7].

2.4. Ethics

According to Swedish healthcare law (SFS 1982:763), healthcare providers are required to systematically improve the quality of care. This retrospective study was hence a quality improvement project initiated by the chief physician of the unit effectuating PRF. According to §37 of the Declaration of Helsinki, an unproven intervention may be used in clinical practice if, in the physician's judgement, it offers hope to alleviate suffering, but there is also an obligation to make this intervention the object of research and, if appropriate, publish this research. As the positive effect of a broad use of PRF in clinical practice has not been scientifically demonstrated [13], this "obligation" to publish was deemed relevant. The retrospective handling of medical records data was reported to the relevant authorities according to the Swedish Personal Data Act (*Personuppgiftslagen*, SFS 1998:204).

2.5. Statistics

Data were primarily analysed descriptively. The chi-square test and the independent t-test were also used as appropriate. IBM SPPS version 23 was used for all analyses.

3. Results

3.1. Overview of the patient cohort

A total of 238 patients received 587 interventions from 2009 to 2014. Thirty-six patients (15%) underwent only a diagnostic test block using a local anaesthetic, i.e., the test block did not lead to treatment with PRF. Hence, 202 patients were actually treated with PRF; 100 (49.5%) of them had previously had a corresponding diagnostic test block, and 102 (50.5%) were treated with PRF directly, without any previous diagnostic test block. The age at first PRF was 55 (15–94) years (mean, range), and 65% were female. A total of 445 PRF interventions were performed on these 202 patients, and few patients were treated more than three times (Fig. 1). Clinical diagnoses according to the International Classification of Diseases version 10 (ICD-10) are listed in Table 1. CLBP was by far the most common diagnosis (57% of patients).

Table 1
Diagnoses according to the International Classification of Diseases (ICD-10).

Diagnosis	ICD-10 code	Frequency (% of all diagnoses)
Chronic low back pain	M54.5	57%
Lumbago with sciatica	M54.4	9%
Neuralgia, unspecified	M79.2	7%
Pain in thoracic spine	M54.6	3%
Cervicocranial syndrome	M53.0	2%
Cervicobrachial syndrome	M53.1	2%
Coccygodynia	M53.3	2%
Pain in limb	M79.6	2%
All other diagnoses		16%

Dichotomizing data into responders (i.e., minor or major improvement) and non-responders (i.e., worsened or no change), we found that, out of 63 responders to a median branch diagnostic test block (either at the cervical or lumbar level), 33 were responders to the first following MB-PRF and 30 were non-responders. Hence the positive predictive value of a median branch test block was $33/63 \times 100 = 52\%$.

3.2. Chronic low back pain

In 127 patients out of 202 treated with PRF, the lumbar level was targeted for a MB-PRF because of clinically suspected lumbar facetogenic pain (255 interventions). Twenty-one percent of patients had had previous lumbar surgery. Looking at the first lumbar MB-PRF (127 patients), 30% experienced major improvement after 1 month, 16% minor improvement, 36% no change, 5% a worsened situation, and the effect was not assessable in 13% of patients (Fig. 2). There was no statistically significant difference in treatment effect between patients who had previously had a corresponding diagnostic test block (60% of cases) and those who had not (40% of cases) ($p = 0.698$). Further, no statistical association was found between effect and previous surgery, sex, or side of the block (right, left, or bilateral). However, patients experiencing major or minor improvement after MB-PRF tended to be younger than patients experiencing no change or worsening pain: 53 (±14) years vs. 59 (±15) years (mean ± SD, $p = 0.039$).

Lone DRG L2-PRF for suspected discogenic lumbar pain was done on 39 patients (43 interventions). In 64% of patients, this was done after a MB-PRF (i.e., when the patient did not improve after

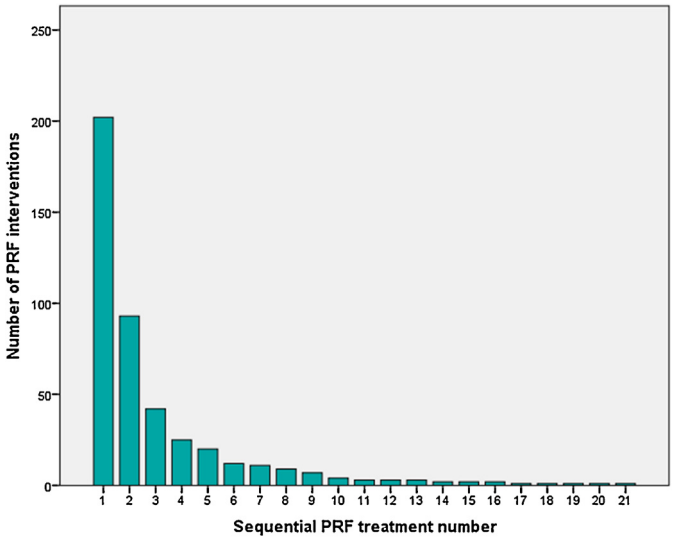

Fig. 1. Number of sequential unspecified pulsed radiofrequency (PRF) interventions during the study period.

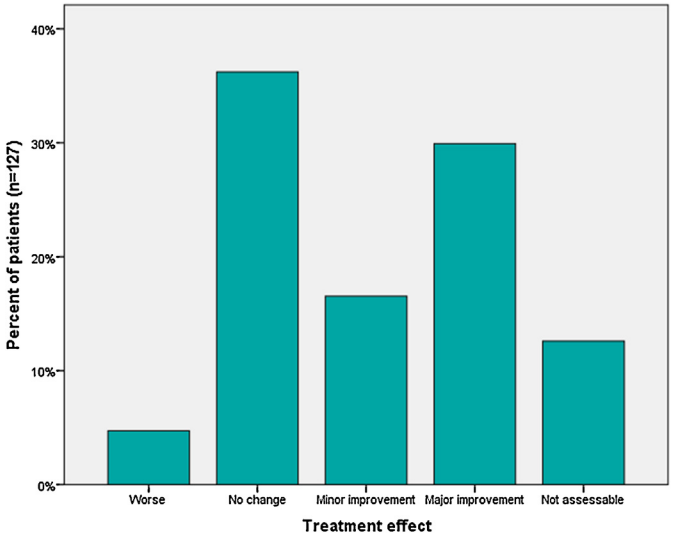

Fig. 2. Effect of the first median branch pulsed radiofrequency treatment (MB-PRF) in 127 patients with suspected lumbar facet joint pain. Retrospective assessment after one month, based on the medical records.

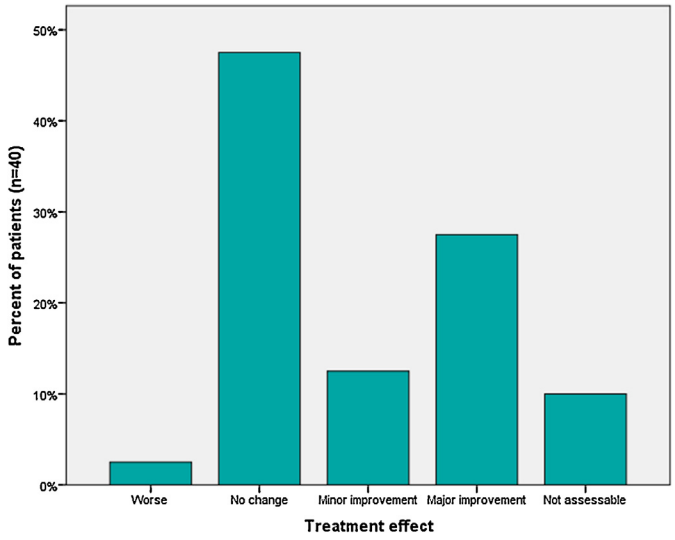

Fig. 3. Effect of the first pulsed radiofrequency treatment (PRF) against a dorsal root ganglion or a peripheral nerve in 40 patients. Retrospective assessment after one month, based on the medical records.

MB-PRF). One month after DRG L2-PRF, the effect was not assessable in 17% of patients, 14% had major improvement, 14% minor improvement, and 55% had no change.

3.3. Dorsal root ganglion or peripheral nerve

In 40 patients, a DRG or a PN was targeted for PRF (62 interventions). There was a plethora of indications, but retrospectively looking at the ICD-10 diagnoses (Table 1), we found that the most common indication was by far related to some form of neuropathic pain (52% of interventions, mainly because of a neuralgia diagnosis), followed by shoulder pain (8% of interventions). Thirty-three percent had had previous surgery in the treatment area. For DRG L2-PRF for suspected discogenic pain, see above. Looking at the first PRF (40 patients), the effect after 1 month was not assessable in 10% of patients, 28% experienced major improvement, 13% minor improvement, 48% no change, and 3% a worsened situation (Fig. 3). No association was found between effect and previous surgery, sex, side of the block (right, left, or bilateral), or age.

4. Discussion

For obvious ethical reasons, it is important to continuously evaluate the effectiveness of available treatment methods, especially if there is widespread use without strong evidence. PRF is used worldwide and much anecdotal evidence exists in its favour, but there are few high-quality studies substantiating its effectiveness. Its widespread use was questioned by Kvarstein in 2012 [13], and that editorial is an important background to the present study of real-life patients. We have shown that the effect size of a broad and indiscriminate clinical use of PRF, whether on MB, DRG or PN, is not particularly impressive. The long-term effects (>1 month) of PRF were not retrospectively assessable, and the present discussion is therefore limited to short-term effects. This time frame limitation is of course a major drawback. On the other hand, if the short-term benefits of a treatment modality are poor, there is not any pressing need for a long-term follow-up. The lack of information on function, health-related quality of life, consumption of analgesics, and psychometric data is also an obvious limitation.

Treatment effect was retrospectively assessed according to the wording of the medical records. This limitation illustrates the need to implement rigorous routines in clinical practice concerning pain assessment (e.g., following the IMMPACT recommendations [14]) before and after an intervention. This should not be only related to prospective studies. Rather, the implementation of rigorous follow-up routines, combined with the searchability of today's electronic records, could lead to reliable large-scale assessments of the effect of different interventions in real-life patients. Another complementary possibility is the expanded use of registries, such as the Swedish quality registry for pain rehabilitation (SQRP), which is a registry designed for patients referred for chronic pain rehabilitation [15]. All in all, clinical quality follow-up projects such as the one described here would be much more feasible if such routines were implemented in clinical practice.

The majority of patients treated in the present study had CLBP. The pain mechanisms driving unspecific back pain are difficult to disentangle in the individual patient. A positive median branch diagnostic test block has been called "the strongest indicator for lumbar facet pain" [6] but, when looking at these diagnostic blocks *per se*, the rate of false positives ranges from 25% to 44% in different lumbar level studies [16]. Looking at the relationship between test blocks and the effect of MB-PRF (mainly at the lumbar level, but also in a few cases at the cervical or thoracic levels), we found a positive predictive value of only 52% for median branch diagnostic test blocks in patients with suspected facetogenic pain. In clinical practice, a negative test block does not warrant a MB-PRF, and we therefore could not calculate the negative predictive value of this test procedure.PRF can hardly be considered the gold standard for facetogenic pain (the evidence for CRF is stronger [1]), and therefore it is possible that the positive predictive value of the test block would have been higher if CRF had been used instead of PRF. This is, however, speculative thinking, and the rather low positive predictive value of the diagnostic test blocks can be ascribed to other factors than the choice of radiofrequency method, e.g., spread of local anaesthetics to surrounding pain-generating structures [6]. It has even been said that "given the close proximity of the ramus lateralis and intermedius to the ramus medialis (medial branch) of the primary ramus dorsalis, it is not possible to selectively block one without the others" [6]. If this is true, the interpretation of median branch test blocks is indeed a difficult problem.

What all of this illustrates is how difficult it is to ascertain the pain mechanism in the individual CLBP patient. Indeed, estimates of the prevalence of facetogenic CLBP vary a lot in the literature, ranging from 5% to 41% of all cases of CLBP [6,8]. We must face the truth that we still do have limited diagnostic capabilities concerning the identification of the structures generating chronic back pain in the individual patient. More research is urgently needed in this area. Hence, in this highly selected population of patients at an academic tertiary pain centre, the overall treatment effects of MB-PRF for CLBP were difficult to interpret. The value of PRF as an alternative to CRF in CLBP needs to be investigated further, perhaps in an RCT comparing PRF to CRF. There are such studies [17,18], but they are rather small and it would perhaps therefore seem sensible to at least consider repeating them. As of today, the evidence seems to favour CRF over PRF for the treatment of facetogenic pain [1].

The algorithm for low back pain *ad modum* Sluijter [7] has influenced our clinical practice, not least concerning the order of PRF interventions, facetogenic pain being investigated before discogenic pain. Concerning the latter, DRG L2-PRF has been recommended [7]. However, targeting the ramus communicans instead seems to have a more solid evidence base [19]. Indeed, the effectiveness of neural blocks of DRG L2 (and L1) for discogenic pain has been strongly called into question in a small case series [20], and the treatment effect of DRG L2-PRF in our case series was modest. Almost two thirds of these patients had previously unsuccessfully been treated with lumbar MB-PRF, this being in accordance with the algorithm *ad modum* Sluijter [7].

Strikingly, looking at all patients (and not just CLBP), 50% of patients were treated with PRF without a previous diagnostic test block. While this might be justified from the point of view of safety (PRF is a non-destructive method), this liberal attitude to diagnostic test blocks is not consistent with established recommendations [6]. The high frequency of patients treated without previous diagnostic block came as a surprise, and it shows how important it is to actually evaluate clinical practice. For the most common procedures (lumbar MB-PRF), the success rate of PRF did not differ between the group who had had a test block vs. the group who hadn't. However, due to the risk of bias, it is difficult to draw any conclusion from this observation. All in all, a practical conclusion from this quality control study was that the practice of diagnostic test blocks had to be sharpened up. As a contrast, the rigorous methodology and excellent results achieved by MacVicar et al. [21], who in a case series followed the guidelines of the International Spine Intervention Society, are an important inspiration for clinical pain interventionists.

DRG-CRF should not be used [10]. Arguably, this should also by extension apply to PN-CRF. However, DRG-PRF and/or PN-PRF are interesting possible treatment niches for PRF [3,22,23]. According to Chua et al., the evidence for the use of DRG-PRF in cervical radicular pain is "compelling" [1]. A small randomised placebo-controlled pilot study on patients with chronic lumbar radicular pain did not show any significant effect [3] but DRG-PRF has nonetheless recently, in an otherwise very PRF-critical editorial, been deemed as seemingly effective for the treatment of radicular pain [13]. Indeed, DRG-PRF has been proposed to be part of an algorithm for the treatment of chronic lumbosacral radicular pain, the next step being spinal cord stimulation (at least for so-called failed back surgery syndrome) [23]. Since DRG-PRF is a non-neurodestructive procedure and appears to be safe [23], conducting further studies about this treatment modality in radicular pain conditions seems a sensible step to take.

PN-PRF (i.e., PRF to the axonal part of peripheral nerves) is also a possibility, but it is important to acknowledge that PN-PRF may act via other mechanisms than DRG-PRF; one should not unreflectively equate the one with the other [13]. In the present study, we nonetheless analyzed data on DRG and PN together, amounting to 40 cases. The results were comparable to those of MB-PRF (Figs. 2 and 3), the frequency of "no change" being actually as high as 48%. To complicate matters further, PN-PRF can be used either in peripheral neuropathic pain conditions [11], or as treatment of a well-localized nociceptive pain, e.g. PRF of the suprascapular nerve because of chronic shoulder pain [12,24]. Hence, the PN-PRF group itself was heterogeneous.

5. Conclusions and implications

This study shows that the effect size of a broad and indiscriminate clinical use of PRF, whether on MB, DRG or PN, is not particularly impressive. This is not to say that the method itself is to be dismissed, but its clinical effectiveness has to be investigated further in carefully selected and more homogenous patient groups. One possible and rational future treatment niche for PRF (as opposed to CRF) could be targeting the DRG in patients with chronic radiculopathies [10]. As of today, however, this cannot be said to be based on strong evidence; more studies are needed. Another possible treatment niche for DRG-PRF that needs to be investigated further is postherpetic neuralgia (PHN). Indeed, fewer than half of the patients having PHN reach clinically significant pain reduction with available methods, and many elderly patients (among whom PHN is most prevalent) have also difficulties tolerating available drugs [25].

This paper is also a reminder concerning the importance of diagnostic test blocks. Although the non-destructive nature of PRF allows a certain level of liberalism concerning test blocks, the drawback of this "liberal approach" is evident in the present paper. Concerning MB-PRF for CLBP, the focus should be, on the one hand on refining diagnostic methodologies (which structure is responsible for the generation of pain in the individual patient?) and, on the other hand, perhaps on comparing the effectiveness of PRF and CRF for putative facetogenic pain (e.g., in an RCT)

What the present paper shows is not that PRF should be dismissed outright as an ineffective method *per se*. Although PRF, in the memorable words of Cohen and Van Zundert [26], can be viewed as a "rebel without cause" and "a treatment in search of an indication", it remains a fascinating and intriguing treatment modality. Preclinical scientists have to work more on the basic science underlying PRF, and we who are pain physicians and clinical researchers have to work on carefully controlled or uncontrolled studies of well-defined homogenous patient groups in order to identify possible treatment niches. Only then will the understanding of PRF and its place in pain medicine increase.

Conflict-of-interest statement

There are no conflicts of interest.

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References

[1] Chua NH, Vissers KC, Sluijter ME. Pulsed radiofrequency treatment in interventional pain management: mechanisms and potential indications – a review. Acta Neurochir (Wien) 2011;153:763–71.
[2] Cahana A, Van Zundert J, Macrea L, van Kleef M, Sluijter M. Pulsed radiofrequency: current clinical and biological literature available. Pain Med 2006;7:411–23.
[3] Shanthanna H, Chan P, McChesney J, Thabane L, Paul J. Pulsed radiofrequency treatment of the lumbar dorsal root ganglion in patients with chronic lumbar radicular pain: a randomized, placebo-controlled pilot study. J Pain Res 2014;7:47–55.
[4] Vallejo R, Tilley DM, Williams J, Labak S, Aliaga L, Benyamin RM. Pulsed radiofrequency modulates pain regulatory gene expression along the nociceptive pathway. Pain Physician 2013;16:E601–13.
[5] Van Boxem K, Huntoon M, Van Zundert J, Patijn J, van Kleef M, Joosten EA. Pulsed radiofrequency: a review of the basic science as applied to the pathophysiology of radicular pain: a call for clinical translation. Reg Anesth Pain Med 2014;39:149–59.
[6] van Kleef M, Vanelderen P, Cohen SP, Lataster A, Van Zundert J, Mekhail N. 12. Pain originating from the lumbar facet joints. Pain Pract 2010;10:459–69.
[7] Sluijter ME. Radiofrequency, Part 1 & Part 2. Meggen, Switzerland: FlivoPress SA; 2001.
[8] Manchikanti L, Kaye AD, Boswell MV, Bakshi S, Gharibo CG, Grami V, Grider JS, Gupta S, Jha SS, Mann DP, Nampiaparampil DE, Sharma ML, Shroyer LN, Singh V, Soin A, Vallejo R, Wargo BW, Hirsch JA. A Systematic review and best evidence synthesis of the effectiveness of therapeutic facet joint interventions in managing chronic spinal pain. Pain Physician 2015;18:E535–82.
[9] Maas ET, Ostelo RW, Niemisto L, Jousimaa J, Hurri H, Malmivaara A, van Tulder MW. Radiofrequency denervation for chronic low back pain. Cochrane Database Syst Rev 2015;10:CD008572.
[10] Dworkin RH, O'Connor AB, Kent J, Mackey SC, Raja SN, Stacey BR, Levy RM, Backonja M, Baron R, Harke H, Loeser JD, Treede R, Turk DC, Wells CD. Interventional management of neuropathic pain: NeuPSIG recommendations. Pain 2013;154:2249–61.
[11] Akural E, Järvimäki V, Korhonen R, Kautiainen H, Haanpää M. Pulsed radiofrequency in peripheral posttraumatic neuropathic pain: a double blind sham controlled randomized clinical trial. Scand J Pain 2012;3:127–31.
[12] Rohof OJ. Radiofrequency treatment of peripheral nerves. Pain Pract 2002;2:257–60.
[13] Kvarstein G. Pulsed radiofrequency—time for a clinical pause and more science. Scand J Pain 2012;3:124–6.
[14] Dworkin RH, Turk DC, Farrar JT, Haythornthwaite JA, Jensen MP, Katz NP, Kerns RD, Stucki G, Allen RR, Bellamy N, Carr DB, Chandler J, Cowan P, Dionne R, Galer BS, Hertz S, Jadad AR, Kramer LD, Manning DC, Martin S, McCormick CG, McDermott MP, McGrath P, Quessy S, Rappaport BA, Robbins W, Robinson JP, Rothman M, Royal MA, Simon L, Stauffer JW, Stein W, Tollett J, Wernicke

J, Witter J. Core outcome measures for chronic pain clinical trials: IMMPACT recommendations. Pain 2005;113:9–19.
[15] Nyberg V, Sanne H, Sjolund BH. Swedish quality registry for pain rehabilitation: purpose, design, implementation and characteristics of referred patients. J Rehabil Med 2011;43:50–7.
[16] Boswell MV, Manchikanti L, Kaye AD, Bakshi S, Gharibo CG, Gupta S, Jha SS, Nampiaparampil DE, Simopoulos TT, Hirsch JA. A best-evidence systematic appraisal of the diagnostic accuracy and utility of facet (zygapophysial) joint injections in chronic spinal pain. Pain Physician 2015;18:E497–533.
[17] Tekin I, Mirzai H, Ok G, Erbuyun K, Vatansever D. A comparison of conventional and pulsed radiofrequency denervation in the treatment of chronic facet joint pain. Clin J Pain 2007;23:524–9.
[18] Kroll HR, Kim D, Danic MJ, Sankey SS, Gariwala M, Brown M. A randomized, double-blind, prospective study comparing the efficacy of continuous versus pulsed radiofrequency in the treatment of lumbar facet syndrome. J Clin Anesth 2008;20:534–7.
[19] Kallewaard JW, Terheggen MA, Groen GJ, Sluijter ME, Derby R, Kapural L, Mekhail N, van Kleef M. 15. Discogenic low back pain. Pain Pract 2010;10:560–79.
[20] Richardson J, Collinghan N, Scally AJ, Gupta S. Bilateral L1 and L2 dorsal root ganglion blocks for discogenic low-back pain. Br J Anaesth 2009;103: 416–9.
[21] MacVicar J, Borowczyk JM, MacVicar AM, Loughnan BM, Bogduk N. Lumbar medial branch radiofrequency neurotomy in New Zealand. Pain Med 2013;14:639–45.
[22] Pope JE, Deer TR, Kramer J. A systematic review: current and future directions of dorsal root ganglion therapeutics to treat chronic pain. Pain Med 2013;14:1477–96.
[23] Van Boxem K, Cheng J, Patijn J, van Kleef M, Lataster A, Mekhail N, Van Zundert J. 11. Lumbosacral radicular pain. Pain Pract 2010;10:339–58.
[24] Liu A, Zhang W, Sun M, Ma C, Yan S. Evidence-based status of pulsed radiofrequency treatment for patients with shoulder pain: a systematic review of randomized controlled trials. Pain Pract 2016;16:518–25.
[25] Johnson RW, Rice AS. Clinical practice. Postherpetic neuralgia. N Engl J Med 2014;371:1526–33.
[26] Cohen SP, Van Zundert J. Pulsed radiofrequency: rebel without cause. Reg Anesth Pain Med 2010;35:8–10.