



ORIGINAL ARTICLE

The effect of consecutive facet medial branch radiofrequency denervation and dorsal root ganglion pulse radiofrequency therapy on lumbar facet joint pain

Ardışık faset medial dal radyofrekans denervasyonu ve dorsal kök gangliyon pulse radyofrekans tedavisinin lomber faset eklem ağrısına etkisi

Gülçin GAZİOĞLU TÜRKYILMAZ,¹ Şebnem RUMELİ²

Summary

Objectives: The aim of this study was to evaluate the efficacy of consecutive facet medial branch (FMB) radiofrequency denervation (RFD) and dorsal root ganglion pulse radiofrequency (DRG PRF) therapy in patients with chronic lumbar facet joint pain.

Methods: The study included 27 patients with chronic lumbar pain who had $\geq 50\%$ pain reduction after FMB block for suspected lumbar facet syndrome and subsequently underwent FMB RFD together with PRF to the adjacent DRG. The patients were retrospectively analyzed in terms of age, gender, pre-procedure symptom duration, history of previous back surgery, FMB RFD and DRG PRF level and side, and numerical rating scale scores immediately before and at 1, 3, and 6 months after the procedure, and subjective pain reduction at 6 months post-treatment. Treatment success was defined as $\geq 50\%$ subjective pain reduction at 6 months.

Results: A total of 19 women and 8 men with a mean age of 57.7 ± 12.4 years were analyzed. Twenty patients (74.1%) had no prior history of low back surgery. The success rate of the procedure in terms of subjective pain reduction at 6 months was 82.5% (n=25). The subjective percentage of pain reduction at post-procedure 6 months was significantly lower in patients with a pre-procedure symptom duration of 12 months or longer compared to those whose pre-procedure symptom duration was < 12 months (p=0.04).

Conclusion: Our study results show that the analgesic efficiency of DRG PRF added to FMD RFD treatment can be increased in patients with short symptom durations.

Keywords: Dorsal root ganglion; facet medial branch; low back pain; pulse radiofrequency; radiofrequency thermocoagulation.

Özet

Amaç: Bu çalışmanın amacı; kronik lomber faset eklem ağrısı tanısı almış hastalarda ardışık uygulanan faset medial dal radyofrekans denervasyonu ve dorsal kök gangliyon pulse radyofrekans uygulamasının lomber faset eklem ağrısı üzerine etkinliğinin değerlendirilmesidir.

Gereç ve Yöntem: Lomber faset sendromu ön tanısı düşünülerek yapılan faset medial dal blokajı sonrası ağrısında %50 ve üzeri iyileşme sağlanabilen ve sonrasında komşu dorsal kök gangliyon pulse radyofrekans ile birlikte faset medial dal radyofrekans denervasyonu uygulanan 27 hastanın yaş, cinsiyet, semptom süresi, geçirilmiş cerrahi öyküsü, faset medial dal radyofrekans denervasyonu ve dorsal kök gangliyon pulse radyofrekans işlemlerinin uygulandığı lomber seviyeleri ve yönleri, işlem öncesi, sonrası birinci ay, üçüncü ay ve altıncı ay sayısal ağrı derecelendirme ölçeği skorları ve altıncı ayda "ağrıda subjektif azalma oranları" retrospektif olarak değerlendirildi. Tedavi başarısı, işlem sonrası ağrının altıncı ayda %50 ve üzeri azalması olarak tanımlandı.

Bulgular: Çalışmaya yaş ortalaması $57,7 \pm 12,4$ yıl olan 19'u kadın, 8'i erkek toplam 27 hasta dahil edildi. Hastaların %74,1'inin (n=20) daha önce bel cerrahisi geçirme öyküsü yoktu. Hastaların altıncı ayda "ağrılarının subjektif azalma oranlarına" göre işlem başarı oranı %82,5 (n=25) olarak bulundu. Bununla birlikte semptom süresi 12 ay veya daha uzun olan hastalarda, kısa olanlara göre, tedavi sonrası altıncı ayda subjektif ağrı azalması oranları daha düşük tespit edildi (p=0,04).

Sonuç: Çalışma sonuçlarımız, semptom süresi kısa olan hastalarda faset medial dal radyofrekans denervasyonu tedavisine eklenen dorsal kök gangliyon pulse radyofrekans uygulamasının analjezik etkinliği artırılabileceğini göstermektedir.

Anahtar sözcükler: Bel ağrısı; faset medial dal; radyofrekans termokoagülasyon; dorsal kök gangliyon; pulse radyofrekans.

¹Department of Pain Medicine, Bursa City Hospital, Bursa, Türkiye

²Division of Pain Medicine, Department of Anaesthesiology and Reanimation, Mersin University Faculty of Medicine, Mersin, Türkiye

Submitted (Başvuru) 16.04.2022 Revised (Revizyon) 06.07.2022 Accepted (Kabul) 07.09.2022 Available online (Online yayımlanma) 17.10.2023

Correspondence: Dr. Gülçin Gazioğlu Türkyılmaz. Bursa Şehir Hastanesi, Ağrı Kliniği, Bursa, Türkiye.

Phone: +90 - 530 - 950 52 79 **e-mail:** drgulcint@gmail.com

© 2023 Turkish Society of Algology

Introduction

Low back pain (LBP) is the most common pain syndrome in society. The lumbar facet joints are a common source of pain and are responsible for between 15% and 45% of chronic LBP.^[1] Radiofrequency denervation (RFD) of the facet joint medial branches (FMB) is commonly performed to treat pain originating from the lumbar facet joints.^[2] However, even when all the recommended conditions for FMB RFD are met, it still may not produce the desired analgesic effect.^[3]

Anatomical studies have failed to fully elucidate the innervation of the lumbar facet joints. However, there is evidence suggesting that facet joint innervation may be more complex, also involving sympathetic trunk branches and adjacent dorsal root ganglia (DRG).^[4,5] Peripheral inflammation has also been implicated as a factor in the onset and persistence of lumbar facet joint pain, and increases in inflammatory mediator release and receptor numbers in the DRG have been reported.^[6] A randomized controlled study comparing the effectiveness of FMB RFD and pulsed radiofrequency (PRF) to the DRG for lumbar facet joint pain showed that DRG PRF provided superior analgesia for 2 years.^[7]

The aim of this study was to evaluate the analgesic efficacy of consecutive FMB RFD and DRG PRF therapy in patients with chronic lumbar facet joint pain.

Material and Methods

Ethical approval for this study was obtained from the Clinical Research Ethics Committee of Bursa City Hospital (date: November 17, 2021, decision number 2021-21/1). The study included patients who presented to the pain outpatient clinic between November 1, 2020, and May 1, 2021, with chronic axial LBP for at least 3 months and met the following inclusion criteria: (1) Numerical Rating Scale (NRS) score ≥ 4 at initial evaluation; (2) unresolved pain after receiving at least one conservative treatment method (medical and/or physical therapy); (3) had suspected facet syndrome based on anamnesis, examination, and imaging (pain that radiates non-specifically to the hips, groin, buttocks, or lower limbs but not to the feet, is triggered by lumbar spine extension or rotating trunk movements, and may be elicited by facet joint palpation, with

facet hypertrophy or degeneration documented by MRI and CT)^[8] in evaluation by the algology department; (4) underwent FMB block in a single session with 0.5 cc local anesthetic and a mixture of steroids at relevant levels and showed $\geq 50\%$ reduction in pain on 10 day after the FMB block; and (5) underwent consecutive FMB RFD and DRG PRF to the adjacent DRG. Exclusion criteria were: (1) NRS score ≤ 4 at initial evaluation; (2) pain control achieved with conservative treatment (medical and/or physical therapy); (3) facet syndrome not suspected based on anamnesis, examination, and imaging in the algology department; and (4) underwent treatment other than consecutive FMB RFD and DRG PRF to the adjacent DRG.

All patients were evaluated by the same algologist, and all FMB block, FMB RFD, and DRG PRF procedures were performed by the same physician (GT). We retrospectively analyzed the patients' pre-procedure symptom duration, previous surgical history, the lumbar level and side on which the FMB RFD and DRG PRF procedures were performed, and the patients' NRS scores before and at 1, 3, and 6 months after the procedure. Patients with missing data for any of these parameters were also excluded from the study.

Diagnostic FMB Block and FMB RFD Procedures

The procedures were performed under mild sedation in the operating room with standard monitoring and fluoroscopic guidance. Midazolam 1–2 mg was administered during sedation with no additional analgesics or opioids. A pillow was placed under the abdomen to minimize lumbar lordosis. The skin was sterilized with standard sterile chlorhexidine and covered with a sterile fenestrated drape. The C-arm was directed cranially or caudally to the end plate of the relevant vertebra, then rotated 15–20° ipsilateral oblique. The cranial aspect of the junction between the medial transverse process and the superior articular process was determined as the target point. After injecting 1 cc of 2% lidocaine at the target point, the tunnel vision technique was used to advance a 10-cm spinal needle to the target point for the nerve block. When contact with the bone was felt, 0.5 cc of a total of 8 cc of a mixture of 1% lidocaine, 0.25% bupivacaine, and 8 mg dexamethasone was administered for each level.



Figure 1. Position of the needle in oblique view during FMD RFD.

Radiofrequency was performed using a 10-cm 22G RF needle with a 10-mm active tip (TOP-Japan). The needle was advanced to the target point using the tunnel vision technique. After making contact with the transverse process, the needle tip was advanced slightly in the cranial direction to slide over the transverse process without losing bone contact. After confirming that the RF cannula was in the facet column on oblique and lateral images (Fig. 1, 2), a 50 Hz sensory stimulus current was applied to the RF generator using a radiofrequency device (TOP-TLG 10 S TP). Paresthesia and tingling in the relevant region were expected with a ≤ 0.5 V sensory stimulus. Correct needle tip placement was confirmed by contraction of the multifidus muscles and the absence of distal muscle contraction in the lower limb with 2 Hz motor stimulation. Before performing RFD, 0.5 mL of lidocaine was injected. Shortly after achieving local anesthesia, RFD was performed for 60 s at 80°C. Nerve localization and technique were the same for the ramus medialis (medial branch) of the L1-L4 nerves. For L5 FMB RFD, the needle was advanced under tun-



Figure 2. Position of the needle in lateral view during FMD RFD.

nel vision towards the notch at the junction of the sacral area and the superior sacral articular process, and the other steps of the RFD procedure were repeated in the same way.

DRG PRF Procedure

The target point was determined as a point just below the pedicle with the fluoroscopy vertebral endplate at the relevant level in a straight and 20° ipsilateral oblique position (Fig. 3). Skin infiltration with 1 cc of 2% lidocaine was administered to the target point. The RF needle was positioned so as not to pass the middle of the pedicle column in the AP view or the middle of the intervertebral foramen in the lateral view (Fig. 4). After ensuring proper positioning of the RF cannula, 50 Hz sensory stimulation was performed using a radiofrequency device. Paresthesia in the area corresponding to the relevant nerve dermatome was expected at < 0.6 V, then 2 Hz motor stimulation was applied, and a confirmatory motor response in the lower limb was sought at 1.5 times the sensory threshold. After observing the appropriate responses, PRF was performed at 45 V and 42°C for 4 min.

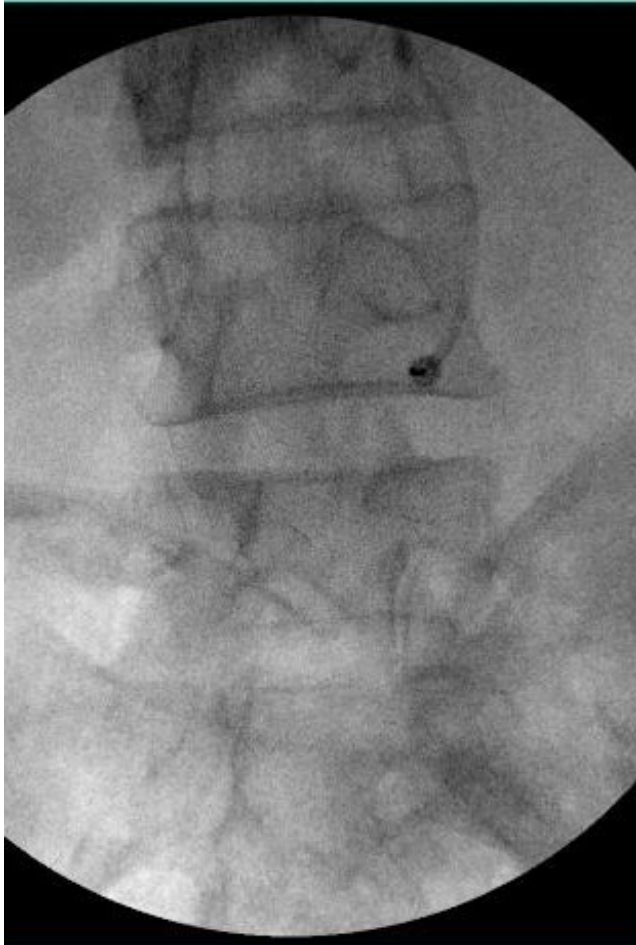


Figure 3. Position of the needle in oblique view during DRG PRF.

Facet Joint Pain Follow-up Procedure

Patients who were suspected of having facet syndrome as a result of anamnesis, examination, and imaging methods underwent a single session of FMD block at the lumbar levels from which the pain was thought to originate. For the FMD block, 0.5 cc of steroid and a local anesthetic mixture was applied at each target level. The patients' pain was evaluated in an outpatient follow-up visit 10 days later. FMD RFD was planned for patients who reported $\geq 50\%$ reduction in pain on day 10 after the FMD block. For patients in whom the RFD cannula could not be positioned parallel to the medial facet nerve during FMD application, the FMD RFD procedure was performed with the tunnel vision technique, and then DRG PRF was applied to the adjacent DRG levels. The NRS values and subjective percentage of pain relief of patients treated with FMD RFD and DRG PRF were recorded in outpatient follow-up visits at 1, 3, and 6 months after the procedure.

Evaluation of Pain Improvement

The patients' NRS scores before the procedure and

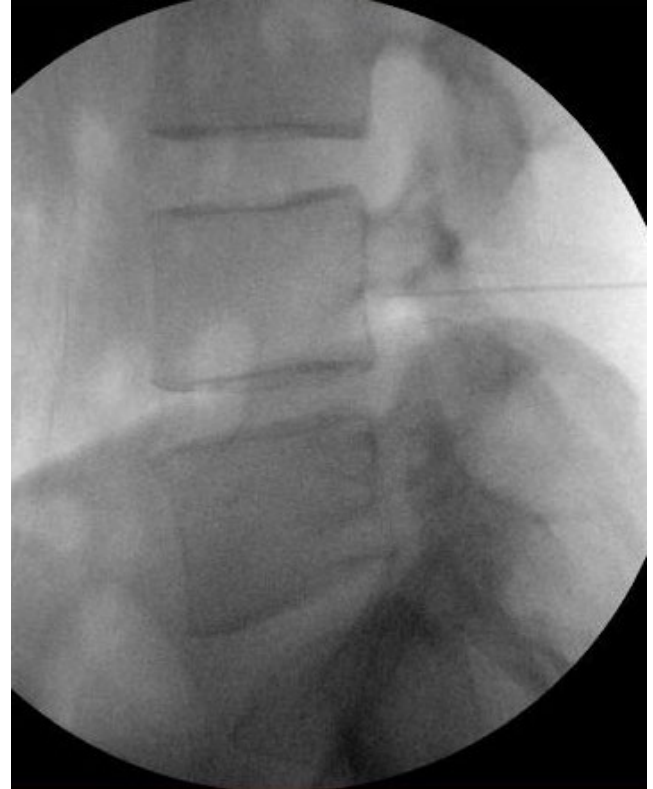


Figure 4. Position of the needle in lateral view during DRG PRF.

at 1, 3, and 6 months after the procedure and the subjective percentage of pain reduction at 6 months after the procedure were analyzed from their medical records. Subjective pain reduction of $\geq 70\%$ was rated as excellent improvement, 50–70% as good, 30–49% as moderate, and $\leq 30\%$ as poor improvement. Success was defined as $\geq 50\%$ pain reduction at 6 months.^[9]

Results

Thirty-three patients underwent consecutive FMB RFD and DRG PRF for lumbar facet joint pain during the study period. Six patients with missing data were excluded. Of the 27 patients analyzed, 19 were women (70.4%) and 8 were men (29.6%). Twenty patients (74.1%) had no prior history of lumbar surgery, while five patients (18.5%) had ≤ 2 previous lumbar surgeries and two (7.4%) had undergone ≥ 3 lumbar surgeries. The patients' demographic data are shown in Table 1.

The distribution of patients in terms of lumbar level and side of the FMB RFD and DRG PRF procedures is shown in Table 2. The most common procedure sites were left L4-5 and L5-S1 for FMB RFD and left L4 and L5 for DRG PRF (29.6%, n=8).

Table 1. Demographic data of the patients

Demographic data	Min	Max	Mean±SD
Age (years)	40	82	57.7±12.4
Pre-procedure symptom duration (months)	3	18	4*
NRS			
Pre-procedure	5	8	5.7±0.9
1 month post-procedure	1	4	1.8±1.0
3 months post-procedure	1	4	1.6±0.8
6 months post-procedure	1	4	1.6±0.8

*: Median; Min: Minimum; Max: Maximum; SD: Standard deviation; NRS: Numerical Rating Scale.

Table 2. Distribution of the patients' FMB RFD and DRG PRF procedures by lumbar level and side

FMB RFD	DRG PRF	Bil.	Rig.	Left
L3-4, L4-5	L3 and L4	1	1	-
L4-5, L5-S1	L4 and L5	5	4	8
L3-4, L4-5, L5-S1	L3, L4, and L5	2	4	2

FMB: Facet medial branch; RFD: Radiofrequency denervation; DRG: Dorsal root ganglia; Bil: Bilateral; Rig: Right.

Table 3. Pain improvement at post-procedure 6 months based on subjective percentage of pain reduction

Improvement	%	n
Moderate (30–49%)	7.4	2
Good (50–70%)	18.5	5
Excellent (≥70%)	74.0	20

Table 4. Distribution of patients by pre-procedure symptom duration

Pre-procedure symptom duration (months)	%	n
3–6	51.8	14
≥6 and <12	18.5	5
≥12	29.6	8

At 6 months after the procedure, none of the patients described poor (≤30%) improvement in pain. The patients' improvement at 6 months after the procedure according to the subjective percentage of pain reduction is shown in Table 3. The success rate of the procedure was 82.5% (n=25). The distribution of patients according to pre-procedure

symptom duration is shown in Table 4. The two patients who reported moderate pain improvement had symptom durations of 12 months or longer. The subjective percentage of pain reduction at post-treatment 6 months was significantly lower in patients with a pre-procedure symptom duration of 12 months or longer compared to those whose pre-procedure symptom duration was <12 months (p=0.04). There was no significant difference between patients with and without a history of prior back surgery in terms of pain reduction or pre-procedure symptom duration (p=0.40 and p=0.64, respectively).

Although complications were not included in our study parameters, no major complications were observed in any of the patients in this study.

Discussion

This is the first study in humans to apply consecutive FMB RFD and dorsal root ganglion pulse radiofrequency (DRG PRF) therapy for chronic lumbar facet joint pain. In this study, treatment with FMB RFD combined with DRG PRF was successful at 6 months post-procedure in 82.5% of patients. However, we observed that longer pre-procedure symptom duration was adversely associated with procedure success.

Clinical examination and radiological imaging methods are known to have limited utility in the diagnosis of lumbar facet joint pain. A consensus practice guideline on interventions for lumbar facet joint pain from a multispecialty international study group stated that medial branch blocks should be the preferred prognostic screening test before lumbar FMB RFD.^[3] There are conflicting reports in the literature regarding the number and nature of diagnostic blocks to administer before FMB RFD.^[3,10–12] The same guideline also stated that diagnostic blocks before FMB RFD can be performed unsedated or under mild sedation without opioids, using a volume of ≤0.5 mL; and that steroids can be administered in addition to local anesthetics to obtain a longer effect during the block; and that a pain decrease of ≥50% after a single-session block can be evaluated as a positive block before RFD. Similarly, our patients who underwent the consecutive FMB RFD and DRG PRF procedures first underwent a pre-procedure FMB block in a single session with 0.5 cc

of a local anesthetic and steroid mixture under mild sedation without opioids. The procedures were performed in patients who reported $\geq 50\%$ reduction in pain on day 10 evaluation.

Although the FMB RFD application is recommended for the treatment of facet joint pain, controversy remains regarding nearly every aspect of the procedure.^[3] Many factors influence the success of the procedure. Some authors have recommended enlarging the lesion size to increase the analgesic efficacy of the FMB RFD procedure.^[13,14] Several studies indicated that positioning the cannula parallel to the nerve increases the size of the lesion and the success of the procedure.^[15,16] In the North American technique, in which the cannula is positioned parallel to the nerve under single-plane anterior-posterior fluoroscopic imaging guidance, successful cannula placement depends on the operator's sense of three-dimensional depth and direction. This technique has a long learning curve, and results vary between operators. Due to these technical difficulties, other authors have suggested using the tunnel vision technique with a 10-mm active tip and a curved needle.^[17] In the consensus practice guidelines mentioned above, methods such as increasing the diameter of the needle cannula, increasing the size of the active tip, increasing lesion time, applying hypertonic serum before lesion generation, and placing the needle parallel to the targeted nerve remain low-level recommendations.^[3] The same guideline states that generating larger lesions relative to the small size of the targeted structures can increase the likelihood of incorporating the targeted structure. However, it is emphasized that when amplifying lesion size, care should be taken to limit the damage to non-target adjacent structures. In our study, in patients for whom the RFD cannula could not be placed parallel to the medial facet nerve during FMD application for various reasons, we used the tunnel vision technique with a 10-cm 22G RF needle with a 10-mm active tip to perform RFD this procedure for 60 seconds at 80°C. The use of different techniques in the FMB RFD procedure and the impact of practitioner experience on the success of the procedure make it difficult to standardize evaluation.

The sensory stimulation threshold, which is used before FMB RFD as a safety measure to prevent in-

advertent damage to the motor nerves during denervation, has also been used as a surrogate marker to determine the proximity of the needle to the target nerve branch. In a retrospective study of 67 patients with sensory stimulation thresholds of <0.5 V and ≥ 0.5 V before FMB RFD, assessment at post-procedure 6 months showed that patients with lower thresholds (<0.5 V) had significantly longer pain relief ($p=0.001$), and the authors concluded that a lower sensorial threshold could improve outcomes.^[18] As stated in the techniques section of the present study, we aimed for pre-procedure sensorial threshold levels of <0.5 V.

There is no definitive and universally accepted description of lumbar facet joint innervation.^[19] In rats, the L5-L6 facet joint was shown to be innervated by the ipsilateral DRG and sympathetic ganglia.^[5] No study has explained the role of the DRG in facet joint innervation in detail. However, an increase in PGE2 receptor (EP2) expression was observed in the DRG in rats with cervical facet joint distraction injuries, and it was concluded that peripheral inflammation was involved in the onset and persistence of facet joint pain. It was suggested that the temporary increase in neuronal EP2 receptor may be due to the migration of some non-neuronal EP2-expressing cells to the DRG, as in other painful joint injuries.^[6] Another animal study demonstrated that after facet joint injury, levels of the inflammatory mediator TNF increased in the innervating DRG neurons.^[20] GABAergic DRG neurons have recently been identified and have been shown to substantially reduce chronic inflammatory pain.^[21] The mechanisms underlying the analgesic effects of DRG PRF therapy are still unclear. In a study evaluating the effects of PRF on inflammatory status in a standard rat muscle injury model, significant reductions in TNF- α , IL-1 β , and IL-6 production were observed in the PRF-treated group, and PRF was shown to be able to inhibit the production of inflammatory markers.^[22] Although DRG PRF is mostly used to treat neuropathic pain, it can offer a good and safe therapeutic modality for inflammatory diseases, cancer, and other chronic pain conditions.^[23,24] In our study, DRG PRF may have exerted its effect by reducing the inflammatory response in facet joint pain, thereby contributing to FMB RFD treatment in reducing pain.

There are many studies evaluating the efficacy of DRG PRF in neuropathic pain, but little research has been conducted to evaluate its effectiveness in non-neuropathic pain. One study evaluating the efficacy of DRG PRF in patients with spine-related pain with (n=25) and without (n=17) radicular pain showed comparable significant decreases in NRS values in both groups after 3 months ($p < 0.001$).^[25] There is only one human study investigating the efficacy of DRG PRF in facet syndrome. This randomized controlled study compared the efficacy of DRG PRF and FMB RFD in 150 patients and demonstrated a higher prevalence of analgesia and a better analgesic effect over 2 years in the DRG PRF group (8 min PRF at 42°C, 45 V to the adjacent DRG) compared to the FMB RFD group (3 lesions at 2-mm intervals, 85°C for 90 seconds).^[7] In our study, we observed that FMB RFD therapy at 80°C for 60 seconds performed together with DRG PRF at 42°C and 45 V for 4 minutes in the adjacent DRG yielded successful treatment outcomes at 6 months in 82.5% of patients with facet joint pain.

The limitations of our study are the absence of a control group, the use of only NRS scores for evaluation, the retrospective study design, and the short follow-up period. In addition, patient follow-up and evaluation were conducted by a single physician. Following patients for transient adverse effects during the study period would have been beneficial.

Conclusion

Our study is the first report of DRG PRF performed together with FMB RFD for lumbar facet joint pain. The results suggest that the addition of DRG PRF may increase the analgesic efficacy of FMB RFD for presumed facet joint pain. However, we observed that longer pre-procedure symptom duration was adversely associated with procedure success. We believe this study will guide prospective, long-term, randomized, controlled trials investigating the efficacy of DRG PRF in facet joint pain.

Peer-review: Externally peer-reviewed.

Ethics Committee Approval: The Bursa City Hospital Clinical Research Ethics Committee granted approval for this study (date: 17.11.2021, number: 2021-21/1).

Conflict-of-interest issues regarding the authorship or article: None declared.

References

1. Perolat R, Kastler A, Nicot B, Pellat JM, Tahon F, Attye A, et al. Facet joint syndrome: From diagnosis to interventional management. *Insights Imaging* 2018;9:773–89. [\[CrossRef\]](#)
2. Lee CH, Chung CK, Kim CH. The efficacy of conventional radiofrequency denervation in patients with chronic low back pain originating from the facet joints: A meta-analysis of randomized controlled trials. *Spine J* 2017;17:1770–80.
3. Cohen SP, Bhaskar A, Bhatia A, Buvanendran A, Deer T, Garg S, et al. Consensus practice guidelines on interventions for lumbar facet joint pain from a multispecialty, international working group. *Reg Anesth Pain Med* 2020;45:424–67.
4. Kapetanakis S, Gkantsinikoudis N. Anatomy of lumbar facet joint: A comprehensive review. *Folia Morphol (Warsz)* 2021;80:799–805. [\[CrossRef\]](#)
5. Suseki K, Takahashi Y, Takahashi K, Chiba T, Tanaka K, Morinaga T, et al. Innervation of the lumbar facet joints. Origins and functions. *Spine (Phila Pa 1976)* 1997;22:477–85. [\[CrossRef\]](#)
6. Kras JV, Dong L, Winkelstein BA. The prostaglandin E2 receptor, EP2, is upregulated in the dorsal root ganglion after painful cervical facet joint injury in the rat. *Spine (Phila Pa 1976)* 2013;38:217–22. [\[CrossRef\]](#)
7. Moussa WM, Khedr W, Elsayy M. Percutaneous pulsed radiofrequency treatment of dorsal root ganglion for treatment of lumbar facet syndrome. *Clin Neurol Neurosurg* 2020;199:106253. [\[CrossRef\]](#)
8. Aransay ALS, Valladares AC, Muñoz RC, Parrilla ÁRP, Muñoz IP, Cuello LG, et al. Prospective analysis of radiofrequency denervation in patients with chronic low back pain. *J Spine Surg* 2020;6:703–12. [\[CrossRef\]](#)
9. Arıcı T, Kılıç E. Distal approach for percutaneous radiofrequency thermocoagulation of lumbar medial branches in patients with lumbar facet arthropathy: A retrospective analysis. *Agri* 2020;32:31–7. [\[CrossRef\]](#)
10. Cohen SP, Williams KA, Kurihara C, Nguyen C, Shields C, Kim P, et al. Multicenter, randomized, comparative cost-effectiveness study comparing 0, 1, and 2 diagnostic medial branch (facet joint nerve) block treatment paradigms before lumbar facet radiofrequency denervation. *Anesthesiology* 2010;113:395–405. [\[CrossRef\]](#)
11. Conger A, Burnham T, Salazar F, Tate Q, Golish M, Petersen R, et al. The effectiveness of radiofrequency ablation of medial branch nerves for chronic lumbar facet joint syndrome in patients selected by guideline-concordant dual comparative medial branch blocks. *Pain Med* 2020;21:902–9. [\[CrossRef\]](#)
12. Price C, Reeves B, Ahmad A, Baloch M, Baranidharan G, Correa R, et al. Radiofrequency denervation of the lumbar facet joints: Guidelines for the RADICAL randomised controlled trial. *Br J Pain* 2021;15:251–8. [\[CrossRef\]](#)
13. Provenzano DA, Watson TW, Somers DL. The interaction between the composition of preinjected fluids and duration of radiofrequency on lesion size. *Reg Anesth Pain Med* 2015;40:112–24. [\[CrossRef\]](#)
14. Wang H, Helm ER, Yung H. Effects of anesthetic fluid injectates on lesion sizes in cooled radiofrequency ablation. *Spine (Phila Pa 1976)* 2017;42:E130–5. [\[CrossRef\]](#)

15. De Andrés Ares J, Gilsanz F. Randomized pragmatic pilot trial comparing perpendicular thin electrode versus parallel thick electrode approaches for lumbar medial branch neurotomy in facetogenic low back pain. *Pain Pract* 2020;20:889–907. [\[CrossRef\]](#)
16. Lau P, Mercer S, Govind J, Bogduk N. The surgical anatomy of lumbar medial branch neurotomy (facet denervation). *Pain Med* 2004;5:289–98. [\[CrossRef\]](#)
17. Gofeld M, Faclier G. Radiofrequency denervation of the lumbar zygapophysial joints--targeting the best practice. *Pain Med* 2008;9:204–11. [\[CrossRef\]](#)
18. Shi W, Rudra R, Vu TN, Gordin Y, Smith R, Kunselman AR. Sensory stimulation threshold: A viable tool to improve the outcome of lumbar facet radiofrequency denervation? *J Pain Res* 2021;14:2113–9. [\[CrossRef\]](#)
19. Kapetanakis S, Gkantsinikoudis N. Anatomy of lumbar facet joint: A comprehensive review. *Folia Morphol (Warsz)* 2021;80:799–805. [\[CrossRef\]](#)
20. Sakuma Y, Ohtori S, Miyagi M, Ishikawa T, Inoue G, Doya H, et al. Up-regulation of p55 TNF alpha-receptor in dorsal root ganglia neurons following lumbar facet joint injury in rats. *Eur Spine J* 2007;16:1273–8. [\[CrossRef\]](#)
21. Du X, Hao H, Yang Y, Huang S, Wang C, Gigout S, et al. Local GABAergic signaling within sensory ganglia controls peripheral nociceptive transmission. *J Clin Invest* 2017;127:1741–56. [\[CrossRef\]](#)
22. Brasil LJ, Marroni N, Schemitt E, Colares J. Effects of pulsed radiofrequency on a standard model of muscle injury in rats. *Anesth Pain Med* 2020;10:e97372. [\[CrossRef\]](#)
23. Berta T, Qadri Y, Tan PH, Ji RR. Targeting dorsal root ganglia and primary sensory neurons for the treatment of chronic pain. *Expert Opin Ther Targets* 2017;21:695–703. [\[CrossRef\]](#)
24. Huang RY, Poree L, Ho KY, Tsai SY, Liu YC, Tan PH, et al. Behavioral survey of effects of pulsed radiofrequency on neuropathic and nociceptive pain in rats: Treatment profile and device implantation. *Neuromodulation* 2021;24:1458–66.
25. Hong LW, Chen KT. A real-world evidence of a consecutive treatment of 42 spine-related pain using dorsal root ganglion-pulsed radiofrequency (DRG-PRF). *Clin Neurol Neurosurg* 2020;197:106186. [\[CrossRef\]](#)