Interventional Pain Medicine 4 (2025) 100575

Contents lists available at ScienceDirect

Interventional Pain Medicine

journal homepage: www.journals.elsevier.com/interventional-pain-medicine

A retrospective single arm cohort study evaluating the efficacy of lumbar medial branch radiofrequency ablation using a multi-tined probe and perpendicular approach

Omar Rachdi [a,*], Andrew Stephens [b], Amanda N. Cooper [a], Brook Martin [c], Robert Burnham [d,e,f], Aaron M. Conger [a], Zachary L. McCormick [a], Taylor R. Burnham [a,f]

[a] Department of Physical Medicine and Rehabilitation, University of Utah, Salt Lake City, UT, USA
[b] Department of Physical Medicine and Rehabilitation, University of Rochester Medical Center, Rochester, NY, USA
[c] Department of Orthopedics, University of Utah, Salt Lake City, UT, USA
[d] Division of Physical Medicine and Rehabilitation, Department of Medicine, University of Alberta, Edmonton, AB, Canada
[e] Central Alberta Pain and Rehabilitation Institute, Lacombe, AB, Canada
[f] Vivo Cura Health, Calgary, AB, Canada

ARTICLE INFO

Keywords:
Radiofrequency ablation
Lumbar facet pain
Dual medial branch blocks

ABSTRACT

Summary of background data: Lumbar medial branch radiofrequency ablation (LMBRFA) is an effective treatment for facet joint pain. LMBRFA efficacy was originally demonstrated using a parallel technique. Newly developed RFA probes (*e.g.*, Trident) allow a perpendicular approach (P-LMBRFA), which may simplify the RFA technique and lead to superior treatment success rates. However, further investigation is necessary to determine whether these technologies are associated with improved patient outcomes.

Objectives: Evaluate the effectiveness of P-LMBRFA in patients with confirmed facet pain.

Methods: In this retrospective single-arm cohort study, electronic medical records were used to identify consecutive patients with ≥80 % dual medial branch block-confirmed pain relief who underwent first-time P-LMBRFA between 2016 and 2022. Primary outcomes were ≥50 % Numerical Rating Scale (NRS) pain improvement and the minimal clinically important difference (MCID) on the Pain Disability Quality-of-Life Questionnaire (PDQQ) at 3 months post-treatment. Secondary outcomes included the duration and mean retrospective percentage of pain relief after a successful index P-LMBRFA in individuals who reported a return of their index symptoms.

Results: 174 participants (60.3 % female, 61.3 ± 14.2 years of age, BMI 29.5 ± 6.7 kg/m^2) were analyzed. Success rates for ≥50 % NRS reduction and MCID on the PDQQ at 3 months were 50.6 % (95 % CI = 43.3–57.9 %) and 50.0 % (95 % CI = 42.8–57.2 %), respectively. Of the 88 successful P-LMBRFAs, 60 patients experienced a return of symptoms after 8.7 ± 3.6 months and reported a retrospective mean percentage pain relief of 81.8 % ± 15.8 %.

Discussion/conclusion: Following P-LMBRFA, approximately 50 % of patients reported improvement in pain and disability measures. Extensive, prospective research comparing long-term outcomes of P-LMBRFA and parallel LMRBFA is warranted.

1. Introduction

Pain arising from the lumbar zygapophyseal "facet" joints has been characterized as a common cause of low back pain (LBP) and disability [1]. Lumbar medial branch radiofrequency ablation (LMBRFA) was originally established in the 1970's [2] as a minimally-invasive treatment option for facet-mediated LBP. This procedure attempts to alleviate LBP and associated disability by using heat generated from radiofrequency currents to coagulate the medial branch nerve, thereby interrupting pain signal transmission from the affected lumbar facet joint. LMBRFA was originally demonstrated using a parallel technique, which involves inserting the RFA probe parallel to the course of the

* Corresponding author. University of Utah Department of Physical Medicine and Rehabilitation 590 Wakara Way Salt Lake City, UT 84108, USA.
E-mail address: omar.rachdi@hsc.utah.edu (O. Rachdi).

https://doi.org/10.1016/j.inpm.2025.100575
Received 1 March 2025; Accepted 9 March 2025

medial branch nerve under fluoroscopic guidance. This technique requires careful, precise probe placement to achieve optimal treatment outcomes [3–6]. Previous work has demonstrated that the needle angle approach to achieve a parallel cannula placement with respect to the medial branch nerve varies [7]. Likewise, the course of the medial branch is susceptible to variation [8]. Traditionally, LMBRFA has been performed with monopolar probes [2,9]. Previous work has demonstrated that a parallel approach is necessary to achieve a higher ablation area to cover the transversing medial branch's course [4,6,10].

The ensuing decades have led to advancements in RFA technology and probe design, including the development of multi-tined RFA probes, such as Trident. "Conventional" RFA probes produce lesions along the length (long axis) of the electrode, with minimal lesion projection beyond the electrode's active (distal) tip [2]. Modification of the active tip of the probe to include additional prongs produces a larger RFA lesion [11,12] projected beyond the distal tip of the electrode, permitting the RFA probe to be inserted at a right angle to the targeted medial branch nerve. While there is a lack of high-quality RCTs comparing perpendicular *vs.* parallel techniques, Deng et al. demonstrated that outcomes for pain, disability, quality of life, adverse events, and fluoroscopy exposure time were equivalent between the monopolar and multi-tined cannulae [13]. This perpendicular approach simplifies the RFA technique, may provide an interventional alternative in circumstances of complicated anatomy such as instrumentation, and may improve success rates in treating facet joint-mediated low back pain. There is a paucity of literature evaluating clinical outcomes after perpendicular lumbar medial branch RFA (P-LMBRFA) with multi-tined cannulae.

This study aimed to evaluate the effectiveness of P-LMBRFA with multi-tined cannulae in patients with confirmed facet pain utilizing dual medial branch blocks with ≥80 % symptom improvement.

2. Methods

2.1. Data collection

This study retrospectively examined medical records of consecutive patients from a single physiatry practice who received P-LMBRFA between 2016 and 2022. Approval for this research was granted by the University of Calgary's Conjoint Health Research Ethics Board (ID#: REB20-0355). Eligibility was restricted to patients with (1) mechanical low back pain that was unresponsive to standard conservative treatments, showing clinical signs of lumbar facet joint pain, who (2) received first-time P-LMBRFA procedures with (3) significant pain reduction (80 % or more) following dual fluoroscopically-guided lumbar medial branch blocks, as well as (4) documented pain and functional scores from before and three months after the procedure using and 11-point Numerical Rating Scale (NRS) and the Pain Disability Quality-Of-Life Questionnaire-Spine (PDQQ-S) instrument, respectively. The response to medial branch blocks was assessed through a pain diary, using a 0–10 NRS scale to record pain intensity just before the block and every 30 min for 6 h after the block. Exclusions were made for off-site diagnostic blocks, intervening procedures or injuries between P-LMBRFA and 3-month follow-up, or simultaneous lumbar interventions. Additionally, data was extracted to evaluate the potential influence of age, gender, BMI, smoking status, employment status, exercise participation, and LMBRFA laterality on treatment outcomes.

2.2. Procedures

2.2.1. Lumbar medial branch blocks (LMBBs)

Patients were positioned face-down on a standard fluoroscopy table, and the area of the lumbar spine was then exposed, cleaned, and prepared sterilely according to standard practices. Fluoroscopic imaging was utilized to identify the correct lumbar levels for the procedure. A 22- to 25-gauge needle was carefully advanced under fluoroscopic guidance to the specific nerve target sites. These sites included the junction where the medial transverse processes meet the superior articular processes of the L2, L3, L4, or L5 vertebrae, aiming for the L1, L2, L3, or L4 medial branch nerves respectively, or the curved area of the sacral alae for the L5 dorsal ramus. The placement of the needle was verified from both lateral and anterior-posterior (AP) perspectives, and a small volume of contrast dye was injected to ensure accurate positioning and to rule out any vascular uptake. Afterward, either 0.5 mL of 2 % lidocaine or 0.5 % bupivacaine was administered. The specific local anesthetic used was not disclosed to the patients. Upon discharge, patients were given a 6-h pain diary to record their pain relief as noted above.

2.2.2. P-LMBRFA

Patients were positioned prone on a standard fluoroscopy table, and their lumbar spine was cleaned and prepped in a standard sterile fashion. Fluoroscopic imaging was employed to identify the target lumbar levels. A dosage ranging from one to 2 mL of 1 % lidocaine was administered to numb the skin and the subcutaneous tissue layers above the medial branch nerves targeted for treatment. An 18-gauge multi-tined cannula with 5-mm active tip (Diros Technology Inc, Markham, Ontario, CA) was positioned at the desired level. The probe's tip was placed 2–3 mm inferior to the superior border of the intersection of the superior articular process and the transverse process, visible in an ipsilateral oblique fluoroscopic view. After contacting periosteum, the cannula tines were deployed and the electrode's placement was verified using lateral, ipsilateral oblique, and anterior-posterior fluoroscopic images (Fig. 1). Subsequently, 1 mL of 1 % lidocaine was injected to anesthetize the medial branch nerves before the creation of the lesion. After a 15-s ramp time, lesions were performed for 145 s at 80 °C.

2.3. Data analysis

Data analysis included descriptive statistics, as well as logistic regression analysis with calculation of odds ratios (ORs) and their 95 % confidence intervals (CIs). Primary outcomes included the proportion of participants at 3 months post-treatment with 1) ≥50 % reduction in index pain as measured by an 11-point NRS and 2) the minimal clinically important difference (MCID) on the Pain Disability and Quality of Life Questionnaire-Spine (PDQQ-S). The PDQQ-S is a validated six-question patient-reported measure designed for use in the field of minimally invasive interventional spine care. The MCID value for this questionnaire has been determined as a ≥17 point decrease [14], which is what was chosen as an additional measure of efficacy in our study. Secondary outcomes included the duration and mean retrospective percentage of pain relief after a successful index P-LMBRFA in individuals who reported a return of their index symptoms. Predictor variables included in the logistic regression models were age, gender, exercise participation, employment status (working, not working, or retired), smoking status, and P-LMBRFA laterality (unilateral or bilateral).

3. Results

A total of 174 patients were analyzed. Patient demographic, clinical, and procedure-related variables are presented in Table 1. Of the included participants, 60.3 % were female, with a mean age of 61.3 ± 14.2 years and a mean BMI of 29.5 ± 6.7 kg/m^2. Primary and secondary outcomes are summarized in Table 2. At 3 months post-procedure, 50.6 % (n = 88; 95 % CI = 43.3–57.9 %) and 50.0 % (n = 87; 95 % CI = 42.8–57.2 %) of participants reported ≥50 % NRS reduction and ≥17-point decrease on PDQQ, respectively. Among the 60 patients who experienced a return of their index symptoms after a successful procedure, the mean reported retrospective percentage of pain relief was 81.8 ± 15.8 %, with improvements lasting a mean duration of 8.7 ± 3.6 months following P-LMBRFA. Logistic regression models for ≥50 % NRS reduction and ≥17-point decrease on PDQQ by the selected covariates are summarized in Table 3. Regular exercise was significantly associated

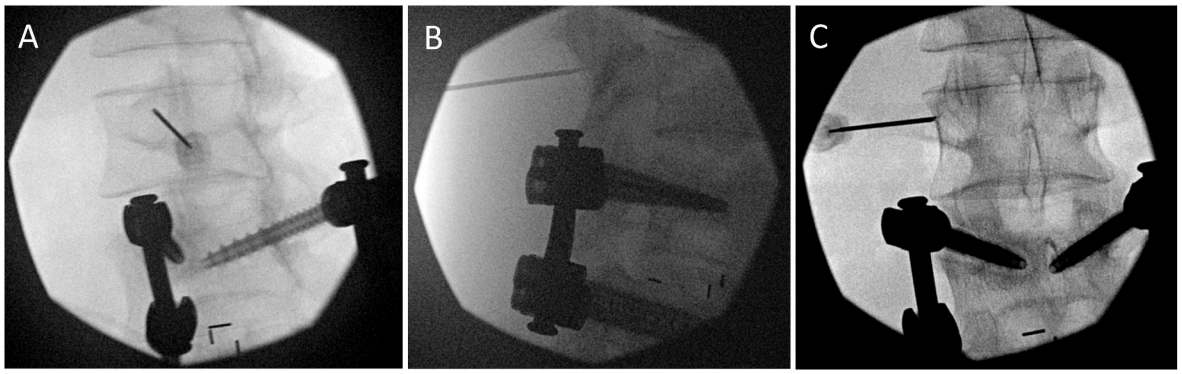

Fig. 1. Fluoroscopic images of (A) oblique, (B) lateral, and (C) anterior-posterior views of radiofrequency ablation of the L2 medial branch nerve showing multi-tined cannula placement and tine deployment.

Table 1
Patient demographic, clinical, and procedural variables ($N = 174$).

Variable	Frequency (%)
Gender	
Male	69 (39.7)
Female	105 (60.3)
Smoker	
Yes	19 (16.7)
No	95 (83.3)
Missing	*60*
Exercise	
Yes	43 (38.7)
No	68 (61.3)
Missing	*63*
Working	
Yes	46 (43.0)
No	13 (12.2)
Retired	48 (44.9)
Missing	*67*
Workup	
Internal	113 (64.9)
External	61 (35.1)
Clinic	
Practice 1	18 (10.3)
Practice 2	156 (89.7)
Laterality	
Unilateral	34 (19.5)
Bilateral	140 (80.5)
Age in years ($n = 174$); mean (SD)	61.3 (14.2)
Body mass index in kg/m^2 ($n = 110$); mean (SD)	29.5 (6.7)
Pain duration in years ($n = 110$); mean (SD)	12.2 (11.6)

SD = standard deviation.

Table 2
Primary and secondary outcomes ($N = 174$).

Outcome	Frequency (%)
≥ 50 % NRS reduction	
Yes	88 (50.6)
No	86 (49.4)
≥ 17-point PDQQ reduction	
Yes	87 (50.0)
No	87 (50.0)
Retrospective percentage pain relief ($n = 55$); mean (SD)	81.8 (15.8)
Retrospective duration of improvement in months ($n = 55$); mean (SD)	8.7 (3.6)

NRS = numerical rating scale; PDQQ = Pain Disability Quality-of-Life Questionnaire; SD = standard deviation.

Table 3
Logistic regression models on ≥ 50 % NRS reduction and ≥17-point PDQQ reduction.

Primary Outcome	Predictor Variable	OR	95 % CI	*p*
≥50 % NPRS reduction[a]	**Gender** (vs. male)			
	Female	1.22	0.49, 3.04	0.66
	Exercise (vs. no)			
	Yes	3.66	1.31, 10.25	**0.01**
	Working (vs. not working)			
	Yes	6.80	1.41, 32.68	**0.02**
	Retired	3.20	0.54, 18.86	0.20
	Smoking (vs. no)			
	Yes	2.99	0.68, 13.10	0.15
	Laterality (vs. unilateral)			
	Bilateral	0.89	0.34, 2.35	0.82
	Age	1.03	0.98, 1.07	0.24
	BMI	1.07	0.99, 1.15	0.08
≥17-point PDQQ reduction[b]	**Gender** (vs. male)			
	Female	1.21	0.48, 3.05	0.68
	Exercise (vs. no)			
	Yes	5.70	2.06, 15.79	**<0.01**
	Working (vs. not working)			
	Yes	2.92	0.63, 13.57	0.17
	Retired	0.84	0.14, 4.87	0.84
	Smoking (vs. no)			
	Yes	4.18	1.00, 17.39	0.05
	Laterality (vs. unilateral)			
	Bilateral	0.87	0.33, 2.29	0.79
	Age	1.04	1.00, 1.09	0.05
	BMI	1.06	0.99, 1.14	0.10

CI = confidence interval; NRS = numerical rating scale; OR = odds ratio; PDQQ = Pain Disability Quality-of-Life Questionnaire.
[a] $N = 99$; χ^2 (8) = 11.82; $p = 0.16$; Pseudo $R^2 = 0.11$.
[b] $N = 99$; χ^2 (8) = 13.00; $p = 0.11$; Pseudo $R^2 = 0.13$.

with both ≥50 % NRS reduction (OR = 3.66; 95 % CI = 1.31–10.25; $p = 0.01$) and ≥17-point decrease on PDQQ (OR = 5.70; 95 % CI = 2.06–15.79; $p < 0.01$) at 3-month follow-up. Additionally, the odds of experiencing ≥50 % NRS reduction at 3 months were nearly seven times higher for participants with active employment compared to non-retired participants who were not working (OR = 6.80; 95 % CI = 1.41–32.68; $p = 0.02$).

4. Discussion

In this retrospective single-arm cohort study, approximately 50 % of participants achieved ≥50 % NRS reduction at three months, indicating a significant improvement in pain. Similarly, 50.0 % of patients reported improvements in PDQQ scores above the MCID threshold, demonstrating meaningful improvement in their overall quality of life and functional ability. Among the 88 patients who experienced successful P-LMBRFA, 60 individuals reported a return of their index symptoms after an average of 8.7 ± 3.6 months. However, it is noteworthy that these patients still reported a retrospective mean percentage pain relief of 81.8 ± 15.8 %, indicating that although the symptoms eventually resurfaced, the initial treatment provided substantial and durable pain relief.

The findings of this study evaluating P-LMBRFA with a multi-tined cannula and perpendicular approach are similar to prior work demonstrating the clinical benefits of LMBRFA as an effective treatment for facet joint pain in appropriately selected patients [15–19] but differ from prior studies evaluating perpendicular approaches utilizing monopolar cannulae [20,21]. Additionally, prior work comparing LMBRFA techniques found that a perpendicular to the nerve approach demonstrated poorer outcomes than a parallel to the nerve approach using a conventional monopolar cannula [6,22]. Schneider et al. demonstrated in their systematic review that post-LMBRFA improvements to pain were greatest among patients selected based on high degrees of pain relief from dual medial branch blocks with an ablation technique employing parallel electrode placement [23]. Their finding of poorer treatment outcomes with a perpendicular approach may be secondary to the relatively small cross-sectional area associated with the ellipsoid lesion produced at the tip of a conventional monopolar cannula. Finlayson et al. reported that multi-tined cannulae demonstrated stable lesion characteristics at varying approach angles in the cervical spine [11]. Additionally, Deng et al. demonstrated that outcomes for pain, disability, quality of life, adverse events, and fluoroscopy exposure time were equivalent between conventional and multi-tined cannulae [13]. Our current study results provide clinical evidence that a perpendicular approach with multi-tined cannulae can provide pain outcomes similar to those of the conventional parallel method.

Additionally, we found that regular exercise and active employment status are associated with greater odds of successful treatment with P-LMBRFA. This is similar to findings for additional spine procedures [24]. Other work has shown that employment status does not correlate with outcomes after spinal procedures [25,26]. Previous work has demonstrated a correlation between experienced pain and psychological distress between unemployment [27] and decreased physical activity [28]. Streitberger and Roelof et al. both found mental health issues to be correlated with poorer outcomes after lumbar RFA [16,29]. It is likely that employed and physically active patients experienced less overall baseline pain and psychological distress and were more likely to report improvement with their procedure.

4.1. Limitations

While these results support the effectiveness of P-LMBRFA, it is important to note that this study lacked a comparative group using the parallel technique, limiting direct comparisons. Thus, further extensive and prospective research is necessary to compare the outcomes of P-LMBRFA and parallel LMBRFA directly. Such studies should consider long-term durability, patient selection criteria, adverse events, cost-effectiveness, procedural discomfort, and patient satisfaction to provide a comprehensive understanding of the clinical benefits of P-LMBRFA. This study was conducted at a single practice utilizing a single-arm retrospective cohort design. The lack of a comparison/control group limits our ability to definitively substantiate the efficacy of this intervention and control for confounding variables. This study is also limited to evaluating outcomes at short-term follow-up (3 months). Given the study's retrospective nature, longer-term follow-up was unavailable for a sufficient number of patients to draw meaningful conclusions. Previous literature has demonstrated, however, that peak effect for lumbar RFA occurs at approximately 3 months [30,31]. Future prospective studies specifically evaluating long-term outcomes up to 12–24 months will be beneficial.

5. Conclusion

The findings from this study support the potential of P-LMBRFA with a multi-tined cannula and perpendicular approach as an effective treatment option for patients with facet joint-mediated low back pain. The results suggest that P-LMBRFA might offer comparable or superior treatment success rates compared to the parallel approach, but head-to-head studies are needed. Continued research and evaluation of P-LMBRFA in larger, prospective studies will help refine the understanding and optimize the application of this innovative technique in clinical practice.

Funding

None.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Zachary McCormick reports a relationship with International Pain and Spine Intervention Society that includes: board membership. Zachary McCormick reports a relationship with Avanos Medical Inc that includes: funding grants. Taylor Burnham reports a relationship with Diros Technology Inc that includes: funding grants. Taylor Burnham reports a relationship with Avanos Medical Inc that includes: consulting or advisory. Aaron Conger reports a relationship with Stratus LLC that includes: funding grants. Robert Burnham reports a relationship with International Pain and Spine Intervention Society that includes: funding grants. Founder and CEO of STATIX, LLC an independent research consulting company - Brook Martin Deputy Editor of Evidence and Methods for The Spine Journal - Brook Martin If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Manchikanti L, et al. Update of utilization patterns of facet joint interventions in managing spinal pain from 2000 to 2018 in the US fee-for-service medicare population. Pain Physician Mar 2020;23(2):E133–49 [Online]. Available: https://www.ncbi.nlm.nih.gov/pubmed/32214289.

[2] Russo M, Santarelli D, Wright R, Gilligan C. A history of the development of radiofrequency neurotomy. J Pain Res 2021;14:3897–907. https://doi.org/10.2147/JPR.S334862.

[3] Bogduk N. Lumbar radiofrequency neurotomy. Clin J Pain May 2006;22(4):409. https://doi.org/10.1097/01.ajp.0000182845.55330.9f.

[4] Bogduk N, Macintosh J, Marsland A. Technical limitations to the efficacy of radiofrequency neurotomy for spinal pain. Neurosurgery Apr 1987;20(4):529–35. https://doi.org/10.1227/00006123-198704000-00004.

[5] Dreyfuss P, Halbrook B, Pauza K, Joshi A, McLarty J, Bogduk N. Efficacy and validity of radiofrequency neurotomy for chronic lumbar zygapophysial joint pain. Spine May 15 2000;25(10):1270–7. https://doi.org/10.1097/00007632-200005150-00012.

[6] Loh JT, Nicol AL, Elashoff D, Ferrante FM. Efficacy of needle-placement technique in radiofrequency ablation for treatment of lumbar facet arthropathy. J Pain Res 2015;8:687–94. https://doi.org/10.2147/JPR.S84913.

[7] Tran J, Campisi ES, Agur AMR, Loh E. Quantification of needle angles for traditional lumbar medial branch radiofrequency ablation: an osteological study. Pain Med May 2 2023;24(5):488–95. https://doi.org/10.1093/pm/pnac160.

[8] Shuang F, et al. Clinical anatomy and measurement of the medial branch of the spinal dorsal ramus. Medicine (Baltim) Dec 2015;94(52):e2367. https://doi.org/10.1097/MD.0000000000002367.

[9] Paul C, Suvar T, Goree J, Sanford J, Srinivasan N, Choi H. Comparisons of monopolar lesion volumes with hypertonic saline solution in radiofrequency ablation: a randomized, double-blind, ex vivo study. Pain Physician Mar 2020;23

(2):159–64 [Online]. Available: https://www.ncbi.nlm.nih.gov/pubmed/32214295.
[10] Feigl GC, et al. Thermocoagulation of the medial branch of the dorsal branch of the lumbal spinal nerve: flouroscopy versus CT. Pain Med Jan 1 2017;18(1):36–40. https://doi.org/10.1093/pm/pnw116.
[11] Finlayson RJ, Thonnagith A, Elgueta MF, Perez J, Etheridge JB, Tran DQ. Ultrasound-guided cervical medial branch radiofrequency neurotomy: can multitined deployment cannulae Be the solution? Reg Anesth Pain Med Jan/Feb 2017;42(1):45–51. https://doi.org/10.1097/AAP.0000000000000506.
[12] Bruners P, Lipka J, Gunther RW, Schmitz-Rode T, Mahnken AH. Bipolar radiofrequency ablation: is the shape of the coagulation volume different in comparison to monopolar RF-ablation using variable active tip lengths? Minim Invasive Ther Allied Technol 2008;17(5):267–74. https://doi.org/10.1080/13645700802384122.
[13] Deng G, Smith A, Burnham R. Prospective within subject comparison of fluoroscopically guided lumbosacral facet joint radiofrequency ablation using a multi-tined (trident) versus conventional monopolar cannula. Pain Physician Aug 2022;25(5):391–9 [Online]. Available: https://www.ncbi.nlm.nih.gov/pubmed/35901480.
[14] Alycia Amatto AS, Pan Bo, Al Hamarneh Yazid, Burnham Taylor, Burnham Robert. An assessment of the minimal clinically important difference for the pain disability quality-of-Life Questionnaire-Spine. Intervent. Pain Med. 2022;1(3). https://doi.org/10.1016/j.inpm.2022.100116.
[15] MacVicar J, Borowczyk JM, MacVicar AM, Loughnan BM, Bogduk N. Cervical medial branch radiofrequency neurotomy in New Zealand. Pain Med May 2012;13(5):647–54. https://doi.org/10.1111/j.1526-4637.2012.01351.x.
[16] Streitberger K, Muller T, Eichenberger U, Trelle S, Curatolo M. Factors determining the success of radiofrequency denervation in lumbar facet joint pain: a prospective study. Eur Spine J Dec 2011;20(12):2160–5. https://doi.org/10.1007/s00586-011-1891-6.
[17] Nath S, Nath CA, Pettersson K. Percutaneous lumbar zygapophysial (Facet) joint neurotomy using radiofrequency current, in the management of chronic low back pain: a randomized double-blind trial. Spine May 20 2008;33(12):1291–7. https://doi.org/10.1097/BRS.0b013e31817329f0. ; discussion 1298.
[18] 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 Jul-Aug 2007;23(6):524–9. https://doi.org/10.1097/AJP.0b013e318074c99c.
[19] van Kleef M, Barendse GA, Kessels A, Voets HM, Weber WE, de Lange S. Randomized trial of radiofrequency lumbar facet denervation for chronic low back pain. Spine Sep 15 1999;24(18):1937–42. https://doi.org/10.1097/00007632-199909150-00013.
[20] van Tilburg CW, Stronks DL, Groeneweg JG, Huygen FJ. Randomised sham-controlled double-blind multicentre clinical trial to ascertain the effect of percutaneous radiofrequency treatment for lumbar facet joint pain. Bone Joint Lett J Nov 2016;98-B(11):1526–33. https://doi.org/10.1302/0301-620X.98B11.BJJ-2016-0379.R2.
[21] van Wijk RM, et al. Radiofrequency denervation of lumbar facet joints in the treatment of chronic low back pain: a randomized, double-blind, sham lesion-controlled trial. Clin J Pain Jul-Aug 2005;21(4):335–44. https://doi.org/10.1097/01.ajp.0000120792.69705.c9.
[22] Lau P, Mercer S, Govind J, Bogduk N. The surgical anatomy of lumbar medial branch neurotomy (facet denervation). Pain Med Sep 2004;5(3):289–98. https://doi.org/10.1111/j.1526-4637.2004.04042.x.
[23] Schneider BJ, et al. Systematic review of the effectiveness of lumbar medial branch thermal radiofrequency neurotomy, stratified for diagnostic methods and procedural technique. Pain Med Jun 1 2020;21(6):1122–41. https://doi.org/10.1093/pm/pnz349.
[24] Josh Levin JC, Huynh Lisa, Smuck Matt, Koltsov Jayme, Kesikburun Bilge, Wagner Graham E, Caragea Marc, Kuo Keith. Thoracic transforaminal epidural steroid injection for management of thoracic spine pain: a multicenter cross-sectional study of short-term outcomes. Intervent. Pain Med. 2022;1(1). https://doi.org/10.1016/j.inpm.2021.100004.
[25] Kennedy DJ, Zheng PZ, Smuck M, McCormick ZL, Huynh L, Schneider BJ. A minimum of 5-year follow-up after lumbar transforaminal epidural steroid injections in patients with lumbar radicular pain due to intervertebral disc herniation. Spine J Jan 2018;18(1):29–35. https://doi.org/10.1016/j.spinee.2017.08.264.
[26] McCormick Z, Cushman D, Casey E, Garvan C, Kennedy DJ, Plastaras C. Factors associated with pain reduction after transforaminal epidural steroid injection for lumbosacral radicular pain. Arch Phys Med Rehabil Dec 2014;95(12):2350–6. https://doi.org/10.1016/j.apmr.2014.07.404.
[27] Jackson T, Iezzi A, Lafreniere K, Narduzzi K. Relations of employment status to emotional distress among chronic pain patients: a path analysis. Clin J Pain Mar 1998;14(1):55–60. https://doi.org/10.1097/00002508-199803000-00008.
[28] Fjeld MK, et al. Consistent pattern between physical activity measures and chronic pain levels: the Tromso Study 2015 to 2016. Pain Apr 1 2023;164(4):838–47. https://doi.org/10.1097/j.pain.0000000000002773.
[29] van Wijk RM, et al. Psychological predictors of substantial pain reduction after minimally invasive radiofrequency and injection treatments for chronic low back pain. Pain Med Mar 2008;9(2):212–21. https://doi.org/10.1111/j.1526-4637.2007.00367.x.
[30] McCormick ZL, et al. A pragmatic randomized prospective trial of cooled radiofrequency ablation of the medial branch nerves versus facet joint injection of corticosteroid for the treatment of lumbar facet syndrome: 12 month outcomes. Pain Med Dec 1 2023;24(12):1318–31. https://doi.org/10.1093/pm/pnad107.
[31] Kapural L, et al. A randomized, placebo-controlled trial of transdiscal radiofrequency, biacuplasty for treatment of discogenic lower back pain. Pain Med Mar 2013;14(3):362–73. https://doi.org/10.1111/pme.12023.