

ORIGINAL STUDY

Role of Ultrasound-guided Pulsed Radiofrequency in the Management of Chronic Cervical Radicular Pain

Mohamed A. Elgaidi, MD ^{a,*}, Ahmed Z. Fouad, MD ^b, Karim A. Eldabaa, MD ^a

^a Neurosurgery Department, Faculty of Medicine, Cairo University, Cairo, Egypt

^b Anesthesia Department, Faculty of Medicine, Cairo University, Cairo, Egypt

Abstract

Background data: Cervical radicular pain is a significant community problem secondary to multiple pathologies, mostly disc herniation, and spondylotic foraminal stenosis. Despite conservative treatment, about 10% of patients still suffer chronic pain. Previous clinical studies reported promising results of using fluoroscopy-guided transforaminal pulsed radiofrequency (PRF) and nonparticulate steroid injection. However, there is a risk of vascular or nerve injury.

Purpose: To evaluate the feasibility and efficacy of ultrasound- (US-) guided technique for extraforaminal PRF and dexamethasone injection in managing chronic cervical radicular pain.

Study design: A clinical prospective case series.

Patients and methods: This study was conducted on 15 patients, eight males and seven females, diagnosed clinically and radiologically with cervical radicular pain. All patients underwent US-guided PRF and dexamethasone injection for corresponding extraforaminal nerve root for 6 min using local anesthesia. All patients were followed up at 1, 3, and 6 months regarding pain relief using the numerical rating scale (NRS), and the Neck Disability Index (NDI) percentage was used for evaluating functional disability before and at 6 months after the procedure. The success rate was defined as a $\geq 50\%$ reduction of the mean NRS as compared to the preintervention score.

Results: There were no intra- or postprocedural complications, and there was no neurological or vascular injury. In all included patients, the targeted extraforaminal cervical nerve root was easily counted and identified within the inter-tubercular groove with its underlying bone acoustic shadow. The mean preprocedural NRS was 7.4 (± 0.99 SD), which dropped after the procedure at 1-, 3-, and 6-month follow-up to 3.7, 3.1, and 2.9, respectively. Consequently, the NRS improvement percentage was 60.8% at the 6-month follow-up (p value < 0.001). The NDI percentage decreased from ($70.5\% \pm 4.4$) to (34.5 ± 9.5) at the 6-month follow-up (p value < 0.001). Hence, the percentage of NDI improvement was 51.1% at the 6-month follow-up. The success rate of the technique was 66.7% (10/15) at the 6-month follow-up.

Conclusion: US-guided technique for extraforaminal pulsed radiofrequency and dexamethasone injection is a feasible, reliable, and effective minimally invasive method for managing chronic cervical radicular pain. A randomized comparative study with a control group and a longer duration of follow-up is recommended for future studies.

Keywords: Brachialgia management, Cervical disc prolapse, Cervical radicular pain, Cervical spondylosis, Foraminal stenosis, Pulsed radiofrequency, Ultrasound-guided

Introduction

Cervical radicular pain is a common neuropathic pain, affecting 1:1000 population annually [1]. Intervertebral disc herniation, spondylotic foraminal stenosis secondary to uncovertebral

joints, facet joints, and ligamentum flavum hypertrophy are the most common causes of cervical radicular pain, while tumors and infection are rare causes [2]. Radicular pain is triggered by a complex interaction of mechanical compression and immune and inflammatory mechanisms affecting the dorsal

Received 22 August 2022; revised 23 October 2022; accepted 1 November 2022.
Available online 30 January 2023

* Corresponding author at: Department of Neurosurgery, Cairo University, Egypt.
E-mail address: mohamedelgaidi@gmail.com (M.A. Elgaidi).

Online ISSN: 2974-4822; Print ISSN: 2974-4814; <https://www.advancedspinej.org>



<https://doi.org/10.57055/2974-4822.1273>

2974-4822/© 2023 Advanced Spine Association. This is an open access article under the CC-BY-NC-SA license (<http://creativecommons.org/licenses/by-nc-sa/4.0/>).

root ganglion, a crucial hyperexcited pain-sensitive structure [3].

Although most patients with acute cervical radicular pain recover within three months with conservative treatment, such as wearing a neck collar, physiotherapy, analgesics, muscle relaxants, and neuropathic pain medications [1], few patients (10%) experience chronic pain [1]. Epidural steroid injection via C7-T1 interlaminar or transforaminal periradicular fluoroscopy-guided techniques was used as an adjunct in reducing radicular pain, with success rates ranging from 45% to 65% at 3–6 months follow-up [4–6]. However, its effect is relatively short-term and associated with general endocrinal side effects such as glucose intolerance and local technique-related risks like epidural hematoma, neural or vascular injury, and spinal cord infarction reported with particulate steroids [7,8].

Anterior cervical discectomy and fusion is the standard surgical treatment for a central disc herniation causing myelopathy, significant canal stenosis, or a large lateral disc herniation not responding to conservative treatment, with a long-term success rate of about 90% [9]. Nevertheless, fusion alters the normal biomechanics of the cervical spine, causing a 2.9% reoperation rate annually for adjacent-level disease. In fact, 25% of patients exhibit symptoms of the adjacent-level disease within 10 years following the initial surgery [10].

Alternative minimally invasive therapeutic interventions are required in patients suffering from brachialgia who do not respond to conservative management or epidural steroid injections with a high success rate and a low rate of associated complications. Recently, pulsed radiofrequency (PRF) under fluoroscopic guidance has been effectively used for minimally invasive management of cervical radicular pain [11,12]. However, fluoroscopy identifies only bone; consequently, it may potentially lead to nerve injury or vertebral or radicular arteries injury, resulting in devastating complications, including spinal cord and brainstem infarction [8,13]. Ultrasound (US) has unique advantages as it can verify nerves and vessels and obtain real-time images of body structures without risk of radiation exposure [6,14].

This work aims to evaluate the feasibility and efficacy of the US-guided technique for extraforaminal PRF and dexamethasone injection in managing chronic cervical radicular pain.

Patients and methods

This prospective clinical case series was conducted from June 2021 to February 2022. It included 15 patients with a postprocedural follow-up period of 6 months.

The inclusion criteria were as follows: chief complaint of significant brachialgia (≥ 6 on the numerical rating scale [NRS]) that did not respond to at least three months of conservative treatment in the form of oral anti-inflammatory drugs and/or narcotics for severe pain and physical therapy; history, physical examination, consistent with cervical radicular pain; and Magnetic Resonance Imaging (MRI) of cervical spine documenting ipsilateral foraminal stenosis due to disc herniation or hypertrophy of the joint of Luschka or facet joint. The exclusion criteria included age younger than 18 years, pregnancy, arm or forearm weakness, myelopathy, instability, previous cervical surgery, a cervical vertebral fracture, and coagulopathy.

This study included eight males and seven females with a mean age of 44.3 ± 10.1 (range, 28–62) years. The mean duration of symptoms was 9.9 ± 3 months. All included patients had single-level cervical pathology; eight of them had soft disc herniation, while seven cases suffered from foraminal stenosis. C7 and C6 were the most affected roots (6 cases each), followed by C5 (3 cases). The degree of nerve root compression was evenly distributed among mild, moderate, and severe grades (5 cases each) as described by Rayan et al. [15], who classified the degree of foraminal stenosis into (mild $\leq 33\%$, moderate 36%–66%, and severe $>66\%$ neural foraminal encroachment) (Fig. 1) (Table 1).

The NRS was used to assess the degree of pain, with 0 = no pain and 10 as the worst imaginable pain. Grades 1–3, 4–6, and 7–9 represented mild, moderate, and severe pain, respectively [16]. We recorded preprocedural NRS and again six months after the procedure for comparison and assessment of the significance of possible changes. The success of treatment was defined as a reduction of $\geq 50\%$ of the median NRS at six months.

The functional status was evaluated using the Neck Disability Index (NDI), which consists of 10 items (score of each item 0–5): intensity of pain, personal management, raising objects, reading books, headache, concentration, working, driving, sleeping, and leisure activities [17]. The total score was doubled and expressed as a percentage to handle missing data as driving in patients who cannot drive [18]. A high NDI percentage indicated a more severe functional disability. The NDI percentages were documented before treatment and at follow-up at 6 months for assessment of the significance of possible changes.

The procedure

All patients were lying supine with support under the same shoulder and head rotation about 20° to the

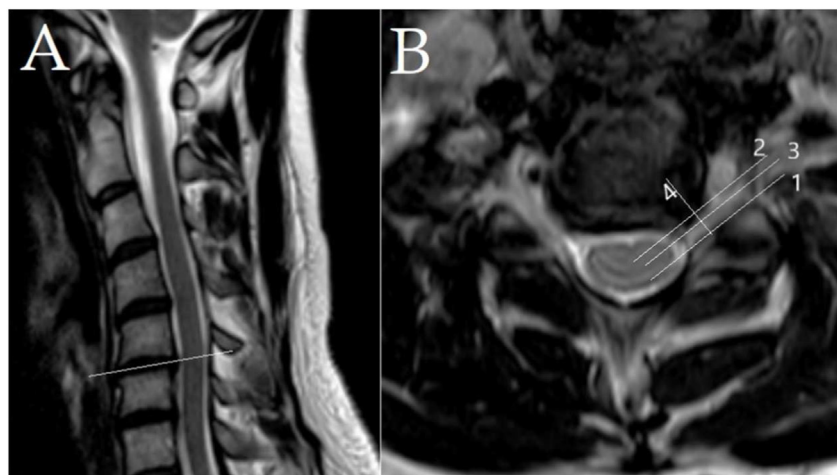


Fig. 1. The assessment of foraminal stenosis degree, MRI T2 (A) sagittal and (B) axial showing left C5–C6 mild (30%) foraminal stenosis due to spondylosis, the compression distance (between lines 2 and 3) \times 100/foraminal width (between lines 2 and 1), according to Rayan et al. [15], mild \leq 33%, moderate 34%–66%, and severe $>$ 66% neural foraminal encroachment.

opposite side, monitored for heart rate, blood pressure, and oxygen saturation, sterilized, and draped.

A 10 MHz linear ultrasound transducer (Mindray DP-15 ultrasound machine) was placed horizontally at the symptomatic neck side. The C7 transverse process was easily recognized by the shadow of its prominent posterior tubercle and rudimentary anterior tubercle. In contrast, the transverse process of C6 has a characteristic sharper and larger anterior tubercle (Chassaignac's tubercle) than the posterior tubercle. By moving the transducer cranially, the C5 transverse process shows the '2-humped camel' sign as the anterior and posterior tubercles are symmetrical. Then, the affected nerve root (for example, the C7 root in the case of C6–C7 disc disease and the C6 root in C5–C6 disc disease) was identified as a hypoechoic structure within the

intertubercular groove (extraforaminal position) with its underlying bony acoustic shadow (Fig. 2).

After local anesthetic infiltration, a 20-gauge, 10 cm (NeuroTherm, Morgan Automation Ltd., Liss, Hants, UK), RF cannula with a 10 mm curved active tip was introduced using an in-plane technique from a posteroanterior direction and positioned between the targeted cervical nerve and posterior tubercle under real-time US-guidance (Fig. 3).

The stylet was replaced by the RF probe connected to the Diros OWL® URF-3AP RF lesion generator with a multilesion adapter, Canada (Fig. 4). The needle position was further adjusted electrically via sensory stimulation (of 50 Hz at 0.3–0.5 V) to induce paresthesia corresponding to the same distribution of the patient's radicular pain followed by motor stimulation (of 2 Hz at 0.8–1 V), which is about double the sensory threshold, on the affected nerve roots resulting in visible arm muscle contractions. The PRF generator was adjusted to give one cycle of 6 min duration of PRF at 45 V with a maximum temperature of 42 °C and an impedance less than 400 Ω , as described by Lee et al. [14]. Finally, an 8 mg/mL dexamethasone solution mixed with 1 ml of 1% lidocaine hydrochloride was injected before needle removal.

Statistical analysis

The collected data were tabulated and analyzed using the computer program IBM SPSS (Statistical Package for the Social Science; IBM Corp, Armonk, NY, USA) release 26 for Microsoft Windows. Categorical data were presented as numbers and percentages, while quantitative data were expressed as mean \pm standard deviation. A paired *t*-test was used as a test of significance in two groups pre- and

Table 1. Characteristics of 15 patients in the study

Parameters	Results
Sex	
Males	8 (53.3%)
Females	7 (46.7%)
Age distribution	
19-	6 (40%)
41-	7 (46.7%)
61-	2 (13.3)
Pathology level	
C5	3 (20%)
C6	6 (40%)
C7	6 (40%)
Pathology type	
Herniated disc	8 (53.3%)
Spondylotic foraminal stenosis	7 (46.7%)
Degree of nerve root compression	
G1	5 (33.3%)
G2	5 (33.3%)
G3	5 (33.3%)

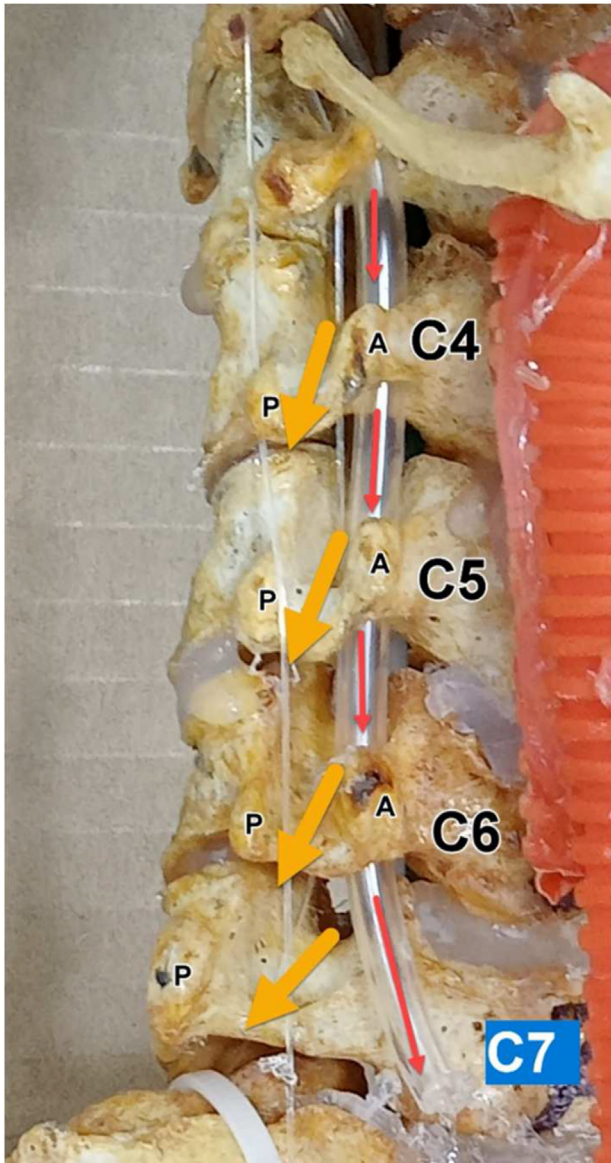


Fig. 2. An anterior-posterior view of the right side of a cervical spine model showing the transverse process of C7 to C4. The yellow arrows refer to nerve roots, and the red arrows refer to the vertebral artery. A) the anterior tubercle, P) the posterior tubercle of the transverse processes. Note C7 transverse process with a prominent posterior tubercle and rudimentary anterior tubercle, C6 transverse process with a characteristic sharper and larger anterior tubercle than the posterior tubercle, and C4–C5 transverse processes with equal anterior and posterior tubercles.

postintervention; an Analysis of variance (ANOVA) test was used as a test of significance in more than two groups; and a post hoc analysis was used to detect significant differences between groups. $P < 0.05$ was considered significant.

Results

In this study, there were no intra- or post-procedural complications, and there was no

neurological or vascular injury. In all included patients, the targeted extraforaminal cervical nerve root was easily counted and identified within the intertubercular groove with its underlying bone acoustic shadow.

The mean preoperative NRS was 7.4 ± 0.99 , which dropped postoperatively at 1-, 3-, and 6-month follow-up to 3.7, 3, and 2.9, respectively (Table 2). The average improvement at the 6-month follow-up was 4.5, which means a 60.8% decline in the average NRS of pain after PRF at the 6-month follow-up. Moreover, the average NDI percentage decreased from 70.5 ± 4.4 before treatment to 30 ± 3.1 at 6 months after treatment. Hence, the percentage of NDI improvement was 51.1% at the 6-month follow-up. A significant reduction in the NDI percentage was observed after treatment (p -value < 0.001). It is worth mentioning that the average improvement percentage of the NRS or NDI scores refers to the proportion of improvement in the corresponding scores compared to the average preoperative score. It was calculated as $(\text{preoperative score} - \text{postoperative score}) / \text{preoperative score} \times 100$. The success rate of the technique, defined as at least a 50% reduction of NRS, was 66.7% at the 6-month follow-up. Four out of the five patients who reported failure suffered from severe nerve root compression (two cases had soft discs and two patients had spondylotic foraminal stenosis).

Discussion

Cervical radiculopathy is a fairly common neurological disorder caused by nerve root dysfunction, which is commonly caused by mechanical compression; however, symptoms can also be caused by inflammatory cytokines generated by herniated intervertebral discs [2]. All patients should be managed conservatively for at least 6 weeks if they do not have myelopathy or significant muscular weakness. Despite conservative therapy, 10–20% of patients continue to experience chronic pain [1].

After cervical transforaminal or interlaminar steroid injections under fluoroscopy guidance, over 50% of patients report experiencing a pain reduction of 50% or more at short- and intermediate-term follow-ups [5,19,20]. Conger et al. [19,20]. compared the effectiveness of catheter-directed cervical interlaminar epidural steroid injection with triamcinolone to cervical transforaminal steroid injection with dexamethasone for treating refractory unilateral radicular pain in a prospective study of 117 patients. The proportions of participants who experienced $\geq 50\%$ pain reduction at 1, 3, 6, and 12 months were

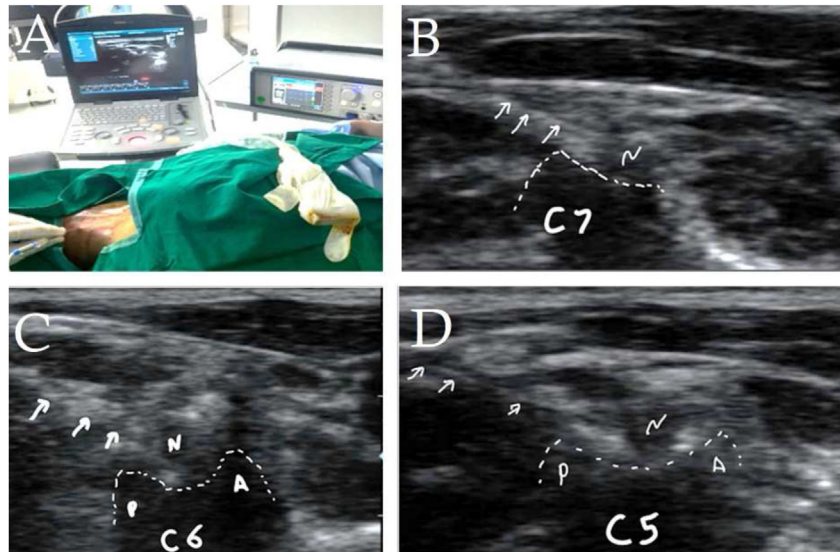


Fig. 3. The steps of the cervical PRF procedure, (A) the patient at the supine position with support under the same shoulder and head rotation (about 20°) to the opposite side, the RF cannula inserted at right C6 during the PRF procedure, (B) C7 transverse process with a prominent posterior tubercle and rudimentary anterior tubercle, (C) C6 transverse process with a characteristic sharper and larger anterior tubercle (Chassaignac's tubercle) than the posterior tubercle, and (D) C5 transverse process with equal anterior and posterior tubercles. A: anterior tubercle; P: posterior tubercle; N: nerve root; the arrows refer to the needle.

68.5%, 59.3%, 60.8%, and 61.2%, respectively, in the catheter group compared with 49.1%, 46.4%, 51.9%, and 51.9%, respectively, in the transforaminal group. There was no statistical difference between groups at 3, 6, and 12 months.

PRF is a novel technique that uses pulsed high-frequency current to avoid a temperature rise to the level of protein denaturation above 42 °C. Therefore, PRF is a relatively safe technique not linked to the risk of motor impairments or deafferentation pain syndrome [21]. On the other hand, conventional radiofrequency has been used successfully for the

treatment of small joints (cervical and lumbar facet joints) and large joints (sacroiliac and knee joints) pain via thermal coagulation of the nociceptive sensory fibers [22].

The mechanism of pain regulation by PRF stimulation has not yet been discovered, but several mechanisms have been suggested. According to Podhajsky et al. [23], PRF resulted in reversible mild endoneurial edema in contrast to Wallerian degeneration caused by thermal injury after CRF. In addition, PRF stimulation raised the c-Fos level in the dorsal horn, possibly triggering a pain-inhibitory mechanism [24]. Moreover, PRF inhibited microglia activity in the dorsal horn. By secreting a number of inflammatory cytokines and chemokines that regulate pain signaling, microglial activation plays a significant role in the emergence of chronic neuropathic pain; hence, downregulating microglial activity by PRF appeared to stop the development of chronic neuropathic pain [25].

Several case studies reported promising results using fluoroscopy-guided PRF in managing cervical radicular pain. Choi et al [11], reported a 66.7% success rate (14/21) at 6- and 12-month follow-ups with PRF for 2 min. Similarly, Yoon et al. [12], reported a 68% success rate (15/22) at six months after PRF for 4 min. The success rate in both clinical studies was defined as $\geq 50\%$ pain relief of cervical radicular pain.

The genuine therapeutic effect of fluoroscopy-guided PRF in cervical radicular pain was confirmed

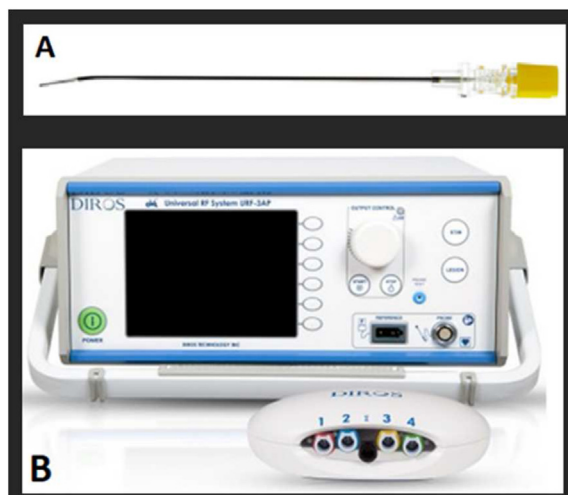


Fig. 4. (A) RF cannula 20 G, 10 cm with 10 mm curved active tip; (B) the Diros OWL® URF-3AP RF lesion generator, with multilesion adapter for four cannulas.

Table 2. The changes in NRS score pre and 1, 3, and 6 months post-RFA

Evaluation time	Study group (15)	p-value	P1 (preoperative)	P2 (1-mo. postoperative)	P3 (3-mos postoperative)
Pre-RFA	7.40 ± 0.99	<0.001			
1 mo. post-RFA	3.67 ± 0.82		<0.001		
3 mos post-RFA	3.13 ± 0.83		<0.001	0.04	
6 mos post-RFA	2.93 ± 1.10		<0.001	0.02	0.3

Post hoc analysis revealed that there was a statistically significant difference between NRS score pre-RFA and 1 month, 3 months, and 6 months after the procedure. There was a statistically significant difference between 1 month, 3 months, and 6 months after the procedure; in addition, there was a statistically nonsignificant difference between 3 months after the procedure and 6 months after the procedure.

by several randomized controlled clinical trials. Van Zundert et al. [26]. reported 63.6% (7/11) successful pain reduction $\geq 50\%$ on NRS) after applying PRF for 2 min at a 6-month follow-up in a randomized controlled trial. Halim et al. [27]. compared PRF for 6 min to percutaneous nucleoplasty in a randomized study of 34 patients at a 3-month follow-up. The VAS improved significantly in both groups without observing a statistically significant difference. Wang et al. [28]. reported a randomized study including 62 patients complaining of cervical radicular pain, divided into three groups. The PRF, nerve root block, and combined techniques via a posterior approach are both equally effective; however, when combined, the results are superior.

On the other hand, the US-guided technique is a radiation-free method that can be safely applied at the extraforaminal position to target the affected cervical nerve root within the intertubercular groove with its underlying bone acoustic shadow without nerve or vessel injury and with negligible complications.

In the current study, a US-guided technique for extraforaminal PRF and dexamethasone injection was used for patients with chronic cervical radicular pain who were unresponsive to conservative treatment. The successful pain relief rate ($\geq 50\%$ on NRS) was 66.7%, and the NDI percentage decreased from 70.5 ± 4.4 to 30 ± 3.1 at 6 months follow-up. Thus, the percentage of NDI improvement was 51.1%. These results are consistent with the results of Lee et al. [14]. who reported (63.3%) successful pain relief at 6 months after US-guided PRF treatment of 49 patients for 6 min

The main limitations of the current study are the limited number of patients, the relatively short follow-up, and the lack of a control group.

Conclusion

Ultrasound-guided technique for extraforaminal pulsed radiofrequency and dexamethasone injection is a reliable and effective minimally invasive method in the short-term management of chronic cervical radicular pain.

Conflicts of interest

The authors report no conflicts of interest.

Acknowledgment

<https://www.medicine.cu.edu.eg>.

Ethics Information

The article does not contain information about medical device(s)/drug(s).

Author declaration of funding statement

No funds were received in support of this work.

Abbreviations

DRG	Dorsal root ganglion
NDI	Neck Disability Index
NRS	Numerical rating scale
PRF	Pulsed radiofrequency
US	Ultrasound

References

- [1] Woods BI, Hilibrand AS. Cervical radiculopathy: epidemiology, etiology, diagnosis, and treatment. *J Spinal Disord Tech* 2015;28:E251–9.
- [2] Abbed KM, Coumans JV. Cervical radiculopathy: pathophysiology, presentation, and clinical evaluation. *Neurosurgery* 2007;60(1 Supp1 1):S28–34.
- [3] Van Zundert J, Harney D, Joosten EA, Durieux ME, Patijn J, Prins MH, et al. The role of the dorsal root ganglion in cervical radicular pain: diagnosis, pathophysiology, and rationale for treatment. *Reg Anesth Pain Med* 2006;31:152–67.
- [4] McCormick ZL, Nelson A, Bhavne M, Zhukalin M, Kendall M, McCarthy RJ, et al. A prospective randomized comparative trial of targeted steroid injection via epidural catheter versus standard C7-T1 interlaminar approach for the treatment of unilateral cervical radicular pain. *Reg Anesth Pain Med* 2017;42:82–9.
- [5] House LM, Barrette K, Mattie R, McCormick ZL. Cervical epidural steroid injection: techniques and evidence. *Phys Med Rehabil Clin* 2018;29:1–17.
- [6] Lee SH, Kim JM, Chan V, Kim HJ, Kim HI. Ultrasound-guided cervical periradicular steroid injection for cervical radicular pain: relevance of spread pattern and degree of penetration of contrast medium. *Pain Med* 2013;14:5–13.
- [7] Malhotra G, Abbasi A, Rhee M. Complications of transforaminal cervical epidural steroid injections. *Spine (Phila PA 1976)* 2009;34:731–9.

- [8] Suresh S, Berman J, Connel D. Cerebellar and brain stem infarction as a complication of CT-guided transforaminal cervical root block. *Skeletal Radiol* 2007;36:449–52.
- [9] Rhee JM, Ju KL. Anterior cervical discectomy and fusion. *JBJS Essential Surg Tech* 2016;6:e37.
- [10] Tobert DG, Antoci V, Patel SP, Saadat E, Bono CM. Adjacent Segment Disease in the Cervical and Lumbar Spine. *Clin Spine Surg* 2017;30:94–101.
- [11] Choi GS, Ahn SH, Cho YW, Lee DG. Long-term effect of pulsed radiofrequency on chronic cervical radicular pain refractory to repeated transforaminal epidural steroid injections. *Pain Med* 2012;13:368–75.
- [12] Yoon YM, Han SR, Lee SJ, Choi CY, Sohn MJ, Lee CH. The efficacy of pulsed radiofrequency treatment of cervical radicular pain patients. *Korean J Spine* 2014;11:109–12.
- [13] Wallace MA, Fukui MB, Williams RL, Ku A, Baghai P. Complications of cervical selective nerve root blocks performed with fluoroscopic guidance. *AJR* 2007;188:1218Y1221.
- [14] Lee SH, Choi HH, Roh EY, Chang MC. Effectiveness of ultrasound-guided pulsed radiofrequency treatment in patients with refractory chronic cervical radicular pain. *Pain Physician* 2020;23:E265–72.
- [15] Ryan AG, Morrissey BM, Newcombe RG, Halpin SF, Hourihan MD. Are T1 weighted images helpful in MRI of cervical radiculopathy? *Br J Radiol* 2004;77:189–96.
- [16] Kremer E, Atkinson JH, Ignelzi RJ. Measurement of pain: patient preference does not confound pain measurement. *Pain* 1981;10:241–8.
- [17] Vernon H, Mior S. The neck Disability Index: a study of reliability and validity. *J Manip Physiol Ther* 1991;14:409–15.
- [18] Riddle DL, Stratford PW. Use of generic versus region specific functional status measures on patients with cervical spine disorders. *Phys Ther* 1998;78:951–63.
- [19] Conger A, Cushman DM, Speckman RA, Burnham T, Teramoto M, McCormick ZL. The effectiveness of fluoroscopically guided cervical transforaminal epidural steroid injection for the treatment of radicular pain; a systematic review and meta-analysis. *Pain Med* 2020;21:41–54.
- [20] Conger A, Kendall RW, Sperry BP, Petersen R, Salazar F, Cunningham S, et al. One-year results from a randomized comparative trial of targeted steroid injection via epidural catheter versus standard transforaminal epidural injection for the treatment of unilateral cervical radicular pain. *Reg Anesth Pain Med* 2021;46:813–9.
- [21] Byrd D, Mackey S. Pulsed radiofrequency for chronic pain. *Curr Pain Headache Rep* 2008;12:37–41.
- [22] Chua NH, Vissers KC, Sluiter ME. Pulsed radiofrequency treatment in interventional pain management: mechanisms and potential indications—a review. *Acta Neurochir (Wien)* 2011;153:763–71.
- [23] Podhajsky RJ, Sekiguchi Y, Kikuchi S, Myers RR. The histologic effects of pulsed and continuous radiofrequency lesions at 42 degrees C to rat dorsal root ganglion and sciatic nerve. *Spine* 2005;30:1008–13.
- [24] Higuchi Y, Bsjr Nashold, Sluiter M, Cosman E, Pearlstein RD. Exposure of the dorsal root ganglion in rats to pulsed radiofrequency currents activates dorsal horn lamina I and II neurons. *Neurosurgery* 2002;50:850–5. discussion 856.
- [25] Cho HK, Cho YW, Kim EH, Sluiter ME, Hwang SJ, Ahn SH. Changes in pain behavior and glial activation in the spinal dorsal horn after pulsed radiofrequency current administration to the dorsal root ganglion in a rat model of lumbar disc herniation: Laboratory investigation. *J Neurosurg Spine* 2013;19:256–63.
- [26] Van Zundert J, Patijn J, Kessels A, Lame I, van Suijlekom H, van Kleef M. Pulsed radiofrequency adjacent to the cervical dorsal root ganglion in chronic cervical radicular pain: a double blind sham controlled randomized clinical trial. *Pain* 2007;127:173–82.
- [27] Halim W, van der Weegen W, Lim T, Wullems JA, Vissers KC. Percutaneous cervical nucleoplasty vs. pulsed radiofrequency of the dorsal root ganglion in patients with contained cervical disk herniation: A prospective, randomized controlled trial. *Pain Pract* 2017;17:729–37.
- [28] Wang F, Zhou Q, Xiao L, Yang J, Xong D, Li D, et al. A randomized comparative study of pulsed radiofrequency treatment with or without selective nerve root block for chronic cervical radicular pain. *Pain Pract* 2017;17:589–95.