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Comparative outcomes of ultrasound- and fluoroscopy-guided cervical medial branch pulsed radiofrequency in chronic facet joint pain: A retrospective cohort study

Kronik faset eklem ağrısında ultrason ve floroskopi rehberliğinde servikal medial dal puls radyofrekans uygulamasının karşılaştırmalı sonuçları: Retrospektif kohort çalışması

Çile Aktan[1], Ece Yanık[2]

[1]Department of Pain Medicine, Antalya Training and Research Hospital, Antalya, Türkiye
[2]Department of Neurology and Pain Medicine, Neuropsychiatry Center, Gazi University, Ankara, Türkiye

ABSTRACT

Background: This study aims to compare clinical outcomes, procedural efficiency, and safety of pulsed radiofrequency (PRF) of the cervical medial branches performed under ultrasound (US) versus fluoroscopy (FL) guidance.

Patients and Methods: This single-center, retrospective cohort study included a total of 177 patients between January 2023 and June 2025. The patients were allocated to FL- (n = 75) or US-guided groups (n = 102). The Numeric Rating Scale (NRS), Neck Disability Index (NDI), and monthly analgesic use were assessed at baseline, at six weeks (primary endpoint), and at three and six months. The primary outcome inter-group NRS at six weeks was analyzed using analysis of covariance adjusted for baseline NRS, age, sex, bilaterality, and number of treated levels. Secondary outcomes included NDI, analgesic use, and procedural metrics. Six-week analyses included all patients; three- and six-month analyses used available-case data (up to n = 141). Last-observation-carried-forward (LOCF) sensitivity analyses were performed.

Results: Of the 177 patients included in the study, 60 were male and 117 were female with a mean age of 53.47 ± 5.46 (range, 39 to 66) years. Compared to FL, US-guided PRF was associated with shorter procedure times (8.64 ± 0.93 *vs.* 14.41 ± 2.24 min), fewer needle redirections (1.36 ± 0.50 *vs.* 3.56 ± 1.02), and fewer minor complications (11.8% *vs.* 30.7%) ($p \leq 0.003$ for all). At six weeks, adjusted mean NRS was 4.46 in US group versus 4.56 in FL group, with no significant inter-group difference (adjusted difference 0.10; 95% confidence interval [CI]: −0.53 to 0.34). No significant differences were observed for NDI or analgesic use at any time point. Responder, longitudinal mixed-effects, and LOCF sensitivity analyses yielded concordant results.

Conclusion: Our study results suggest that US- and FL-guided cervical medial branch PRF can yield similar clinical outcomes. However, US guidance provides procedural and safety advantages without compromising effectiveness.

Keywords: Cervical medial branch, clinical outcomes, fluoroscopy, neck pain, pulsed radiofrequency, ultrasound-guided.

ÖZ

Amaç: Bu çalışmada, servikal medial dallara uygulanan darbeli radyofrekansın (PRF) ultrason (US) ve floroskopi (FL) eşliğinde yapılmasının klinik sonuçları, işlem etkinliği ve güvenliliği karşılaştırıldı.

Hastalar ve Yöntemler: Ocak 2023 ile Haziran 2025 tarihleri arasında bu tek merkezli, retrospektif kohort çalışmaya toplam 177 hasta dahil edildi. Hastalar FL (n = 75) ve US eşliğinde PRF uygulanan (n = 102) gruplara ayrıldı. Sayısal Ağrı Ölçeği (NRS), Boyun Özürlülük İndeksi (NDI) ve aylık analjezik kullanımı başlangıçta, altıncı haftada (birincil sonlanım noktası) ve üçüncü ve altıncı aylarda değerlendirildi. Birincil sonlanım olan altıncı hafta NRS gruplar arası karşılaştırması; başlangıç NRS, yaş, cinsiyet, bilateral tutulum ve tedavi edilen seviye sayısına göre düzeltilmiş kovaryans analizi ile değerlendirildi. İkincil sonuçlar NDI, analjezik kullanımı ve işlemle ilgili parametreleri içerdi. Altıncı hafta analizleri tüm hastaları kapsarken, üçüncü ve altıncı ay analizleri mevcut veriler üzerinden (n = 141'e kadar) yapıldı. Duyarlılık analizleri için son gözlem ileriye taşıma (LOCF) yöntemi kullanıldı.

Bulgular: Çalışmaya dahil edilen 177 hastanın 60'sı erkek, 117'si kadın olup, ortalama yaş 53.47 ± 5.46 (dağılım, 39-66) yıl idi. Floroskopi ile karşılaştırıldığında, US eşliğinde PRF uygulamasında işlem süresi daha kısa (8.64 ± 0.93 dk.'ye kıyasla 14.41 ± 2.24 dk.), iğne yeniden yönlendirme sayısı daha az (1.36 ± 0.50'ye kıyasla 3.56 ± 1.02) ve minör komplikasyon oranı daha düşük (%11.8'e kıyasla %30.7) idi (tümü için $p \leq 0.003$). Altıncı haftada düzeltilmiş ortalama NRS değeri US grubunda 4.46, FL grubunda 4.56 olup gruplar arasında anlamlı fark saptanmadı (düzeltilmiş fark: 0.10; %95 CI: −0.53 ila 0.34). Boyun Özürlülük İndeksi ve analjezik kullanımında hiçbir zaman noktasında anlamlı fark izlenmedi. Yanıtlayıcı analizleri, uzunlamasına karma etkili modeller ve LOCF duyarlılık analizleri tutarlı sonuçlar gösterdi.

Sonuç: Çalışma sonuçlarımız US ve FL eşliğinde uygulanan servikal medial dal PRF'nin benzer klinik sonuçlar sağladığını göstermektedir. Bununla birlikte US eşliğinde uygulama, etkinliği azaltmadan daha kısa işlem süresi ve daha iyi güvenlik profili sunmaktadır.

Anahtar sözcükler: Servikal medial dal, klinik sonuçlar, floroskopi, boyun ağrısı, darbeli radyofrekans, ultrason eşliğinde.

Corresponding author: Çile Aktan, MD.

E-mail: drcilezengin@hotmail.com

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Chronic neck pain is a widespread musculoskeletal disorder that significantly impairs quality of life and imposes a substantial burden on healthcare systems worldwide. Epidemiological studies have shown an increasing prevalence of neck pain and associated disability across diverse populations and regions.[1] This increasing burden highlights the need for effective interventional treatments that target the source of the pain.

The medial branches of the dorsal rami, which innervate cervical facet joints, are a key target for interventional management strategies. Pulsed radiofrequency (PRF) has emerged as an alternative neuromodulatory technique which delivers high-frequency electrical currents in short bursts, thereby avoiding the production of neurodestructive thermal lesions. By maintaining temperatures below 42°C, PRF minimizes tissue damage and offers a safer profile for interventions near motor pathways.[2-5] Recent studies have demonstrated the efficacy and safety of PRF in treating cervical facet joint pain.[6-8] In contrast to conventional thermal radiofrequency (RF), which aims to achieve pain relief through deliberate neurotomy, PRF is designed to exert its effect via neuromodulation without permanent nerve destruction.[2-5] This characteristic has led to its preferential use in anatomically constrained regions such as the cervical spine, where proximity to motor and sensory neural structures raises safety concerns.[2,3,5] Although the comparative efficacy of PRF versus thermal RF remains a subject of ongoing debate, PRF has been increasingly adopted in clinical practice as a more conservative, safety-oriented alternative for cervical medial branch interventions.[4,6-8]

Moreover, bilateral or multi-level conventional thermal RF ablation of the cervical medial branches has been associated with cervical paraspinal muscle denervation and rare, but clinically significant complications, including cervical extensor weakness and dropped head syndrome. These complications have been reported particularly after bilateral applications and multi-level treatments, further supporting the preference for PRF as a non-destructive neuromodulatory alternative in the cervical region, especially when bilateral intervention is planned.[9,10]

Although fluoroscopy (FL) has traditionally been the standard imaging modality for image guidance, it has limitations, including exposure to ionizing radiation, longer procedure times, and poor visualization of soft tissue and vascular structures. In contrast, US-guided interventions are increasingly favored due to its real-time imaging capability, absence of radiation, and portability.[11-13] Comparative studies to date have primarily evaluated ultrasound (US) versus FL for cervical medial branch blocks, rather than PRF; head-to-head data for PRF are lacking.[14,15]

Importantly, evidence specifically addressing US-guided PRF of the cervical medial branches remains limited, with existing data largely extrapolated from studies on diagnostic medial branch blocks or from FL-guided PRF applications.[6-8,14,15] Consequently, the procedural feasibility, efficiency, and safety profile of US-guided PRF in this anatomical region have not been adequately characterized.

In the present study, we aimed to compare US and FL-guided PRF of the cervical medial branch in routine clinical practice. We hypothesized a priori that clinical outcomes would be broadly comparable between the two methods, while US guidance would offer procedural advantages, including shorter procedure time, fewer needle redirections, and fewer minor complications. Accordingly, the study was designed to provide direct, real-world comparative data between US- and FL-guided cervical medial branch PRF.

PATIENTS AND METHODS

This single-center, retrospective cohort study was conducted at Antalya Training and Research Hospital, Department of Pain Medicine, between January 1st, 2023 and June 1st, 2025. Clinical data of patients who underwent cervical medial branch PRF treatment were reviewed. Inclusion criteria were as follows: patients aged between 18 and 80 years who were diagnosed with chronic neck pain of facet joint origin, had experienced pain for at least three months, showed no signs of radicular pain (defined as neuropathic pain originating from the dorsal roots or dorsal root ganglia), and demonstrated a minimum of 50% reduction in pain intensity following at least two separate sessions of diagnostic medial branch blocks were included in the study. Exclusion criteria were as follows: having incomplete baseline or follow-up clinical data, missing procedural documentation, a history of cervical spine surgery, concomitant radicular pain, or having received a cervical epidural steroid injection concurrently during the study period. A total of 202 patients were screened for eligibility; 25 were excluded due to missing procedural information (n = 11) or lack of follow-up data (n = 14). Finally, a total of 177 patients who underwent interventional procedures under FL or US

guidance were included. A written informed consent was obtained from each patient. The study protocol was approved by the Antalya Training and Research Hospital Ethics Committee (Date: 03.07.2025, No: 11/20). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Group allocation and data collection

Due to the retrospective design, allocation to FL- (n = 75) or US-guided groups (n = 102) was non-random. Patients were referred following standard outpatient consultations with a spine surgeon. The imaging modality for each procedure was determined pragmatically by hospital logistics, device availability, and technical capacity at the time of intervention. To minimize selection bias, data extraction was conducted by an independent clinician who was not involved in the interventions. Groups were balanced for key demographic and clinical characteristics to ensure comparability.

Clinical outcomes including Numeric Rating Scale (NRS), Neck Disability Index (NDI), and monthly analgesic use were obtained from standardized follow-up forms routinely implemented in the pain clinic. Procedural variables including the number of needle redirections, FL shots, and adverse events were retrieved from standardized procedural records. Although outcome abstraction could not be blinded to imaging modality due to the retrospective nature of the data, we employed standardized, pre-specified extraction rules. Data abstraction was conducted by an independent physician who was not involved in the procedures or subsequent patient care, thereby minimizing potential observer bias. Group allocation was determined pragmatically based on equipment availability rather than randomization, which may have introduced a risk of selection bias. All data were anonymized before statistical analysis.

Procedures

All interventional procedures were executed under strict aseptic conditions by a Board-certified pain medicine physician with over six years of specialized experience in cervical spine interventions. No procedural sedation was employed. For standardized anatomical orientation and procedural ergonomics, all patients, regardless of the imaging modality used, were positioned in the prone posture. The pain nurse recorded the procedure duration. The procedure time was recorded from the identification of the target to the removal of the needle.

In the US-guided group, a high-frequency linear transducer (10 to 15 MHz) from the Hitachi HI VISION Preirus US system (Hitachi Medical Systems, Japan) was used to identify relevant bony landmarks and trace the trajectory of the cervical medial branches. After skin antisepsis and sterile draping, local infiltration with 1 to 2 mL of 2% lidocaine was administered at the needle entry site for superficial anesthesia. The RF cannula (a 22-gauge hybrid cannula with a 6-cm needle and a 5-mm active tip) was inserted using an out-of-plane approach toward the lateral aspect of the articular pillar. At the C3-C6 levels, the needle tip was directed towards the centrally located hypoechoic oval structure within the hyperechoic "valleys", corresponding to the anatomical position of the medial branches.[16] (Figure 1a, b).

Fluoroscopy-guided procedures

In the FL-guided group, the patients were placed in the prone position and a C-arm FL unit was used

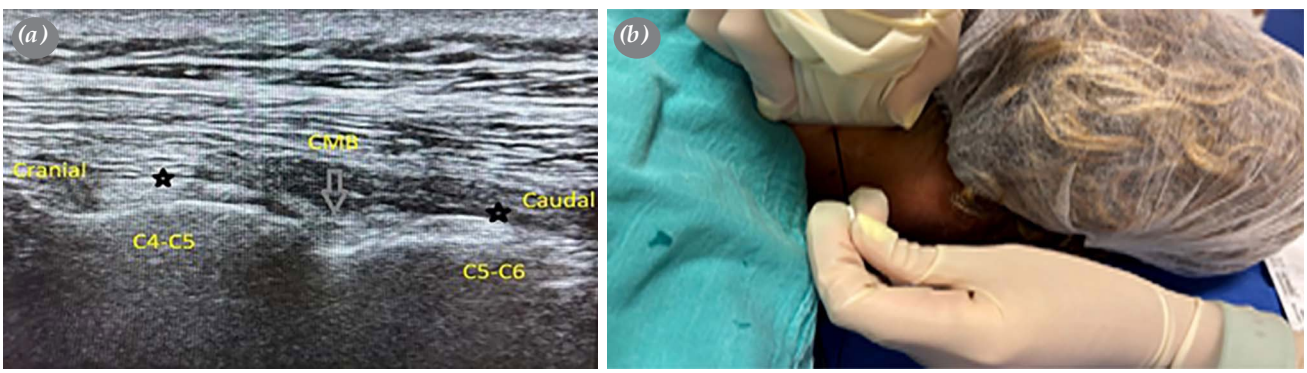

Figure 1. (a) Ultrasound visualization of the cervical medial branch nerve at the C5 level. Sagittal ultrasound image demonstrating the cervical medial branch located between adjacent facet joints at the C5 level. **(b)** Patient positioning and probe and needle placement during the ultrasound-guided procedure.

to visualize the cervical articular pillars. After skin antisepsis and sterile draping, local infiltration with 1 to 2 mL of 2% lidocaine was administered at the needle entry site for superficial anesthesia. The RF cannula (a 22-gauge hybrid cannula with a 6-cm needle and a 5-mm active tip) was advanced toward the radiologically defined target points. Following accurate needle positioning, standard stimulation protocols were applied (Figure 2a, b).

In both procedures, sensory stimulation at 50 Hz (0.3 to 0.5 V) was applied to elicit dermatomal paresthesia, and motor stimulation at 2 Hz was increased to 1.5 to 2.0 V to confirm the absence of motor responses. Upon confirmation, PRF was delivered using a RF generator (Boston Scientific, Marlborough, MA, USA) through a 22-gauge RF cannula (Boston Scientific, Marlborough, MA, USA; 6-cm length, 5-mm active tip) in two consecutive cycles of 120 sec each, at a maximum temperature of 42°C, a pulse frequency of 2 Hz, and a pulse width of 20 msec. Pulsed radiofrequency was preferred over conventional thermal RF, as it is designed as a non-destructive neuromodulatory technique that limits tissue temperature to ≤ 42°C. This approach was considered more appropriate for cervical medial branch interventions in routine practice, where proximity to motor and sensory neural structures warrants a conservative safety profile.

Outcome Measures and Follow-up

We prespecified clinically meaningful response thresholds as ≥ 50% reduction in NRS (consistent with the Initiative on Methods, Measurement, and Pain Assessment in Clinical Trials [IMMPACT] recommendations for substantial pain improvement) and ≥ 40% improvement in NDI (aligned with prior work on the NDI).[17,18]

Pain intensity was assessed using the NRS (0-10), and functional status was measured using the NDI, with raw scores ranging from 0 to 50. NRS and NDI scores were recorded at baseline and at six-week, and three, and six-month follow-up visits.

Monthly analgesic consumption was recorded as the total number of oral analgesic tablets taken over the preceding 30 days (patient self-report). Analgesics included non-steroidal anti-inflammatory drugs, paracetamol, and tramadol preparations. Each tablet/capsule was counted as one unit; non-oral formulations were not recorded.

The primary outcome measure was the inter-group difference in NRS at six weeks.

Secondary outcomes were prespecified as follows:

1. functional disability assessed by the NDI;
2. monthly analgesic consumption (i.e., total number of oral analgesic tablets per 30 days);

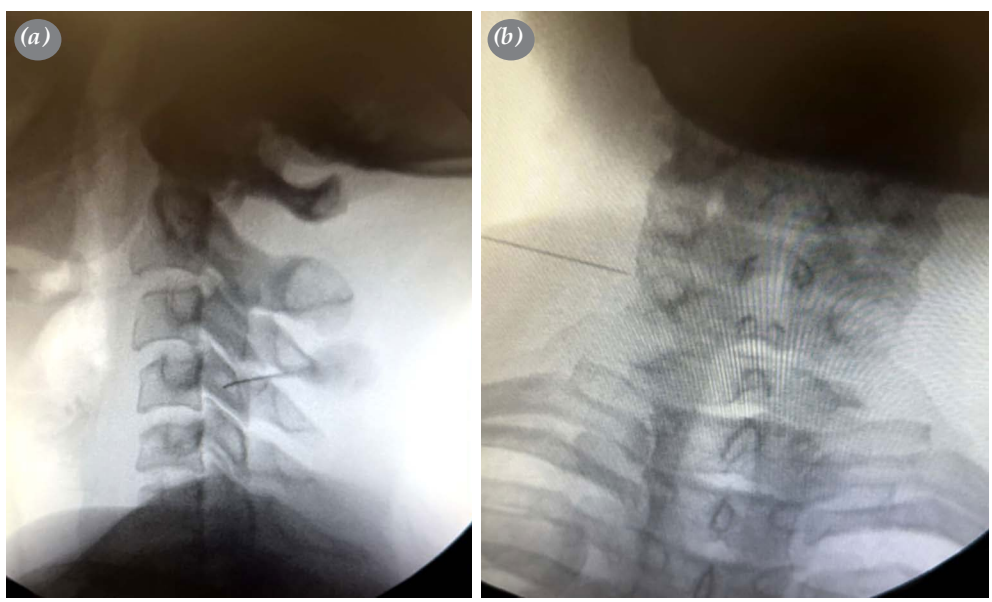

Figure 2. Fluoroscopic guidance for cervical medial branch pulsed radiofrequency. **(a)** Lateral and **(b)** anteroposterior fluoroscopic views demonstrating correct needle placement at the target cervical medial branch (representative level shown).

3. procedural metrics, including procedure duration and the number of needle redirections per treated level; and
4. minor periprocedural complications, including vascular puncture/backflow and post-procedural site pain within 24 hours.

Minor periprocedural complications were prespecified as events occurring intra-procedurally or within 24 hours post-procedure and captured from standardized procedural forms and nursing records. We recorded two categories: 1) vascular puncture/backflow (aspiration of blood or visible vascular entry) and 2) post-procedural site pain requiring observation or additional analgesia. No major complications (e.g., persistent neurological deficit, infection, allergic reaction) were observed.

All patients were advised to begin isometric cervical muscle-strengthening exercises one week after the procedure to support postural control and functional recovery.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 25.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were presented in mean ± standard deviation (SD) or median (min-max), while categorical variables were presented in n and frequency. Normality was assessed using the Shapiro-Wilk test, and variance homogeneity using Levene's test. Inter-group comparisons were conducted using the Welch's t-test or the Mann-Whitney U test for continuous variables, and the chi-square test (with Yates' correction) or Fisher exact test for categorical variables, as appropriate. For continuous outcomes, mean differences with 95% confidence intervals (CIs) and Cohen's d were reported; for categorical outcomes, risk ratios (FL/US) with 95% CIs were calculated. The primary analytic strategy was an inter-group comparison of six-week NRS scores using analysis of covariance (ANCOVA), with imaging modality as the fixed factor and baseline NRS, age, sex, bilaterality, and number of treated levels as covariates. Supportive analyses included comparisons of secondary outcomes (NDI and monthly analgesic use) at six weeks and, at three and six months, available-case contrasts reflecting real-world follow-up (sample sizes varied, up to n = 141). Longitudinal changes over time were further evaluated using a mixed-effects model for repeated measures (MMRM), with visit, modality, and visit × modality as fixed effects, baseline scores as covariates, and an unstructured covariance matrix. Intra-group changes across visits were assessed in all-visit completers using the Friedman test. In contrast, baseline-to-six-week changes in the overall cohort were examined using the Wilcoxon signed-rank test. Multiplicity across secondary inter-group endpoints (NDI and monthly analgesic use at each follow-up time point) was controlled using the Holm-Bonferroni method; the primary endpoint (six-week NRS) was analyzed without multiplicity

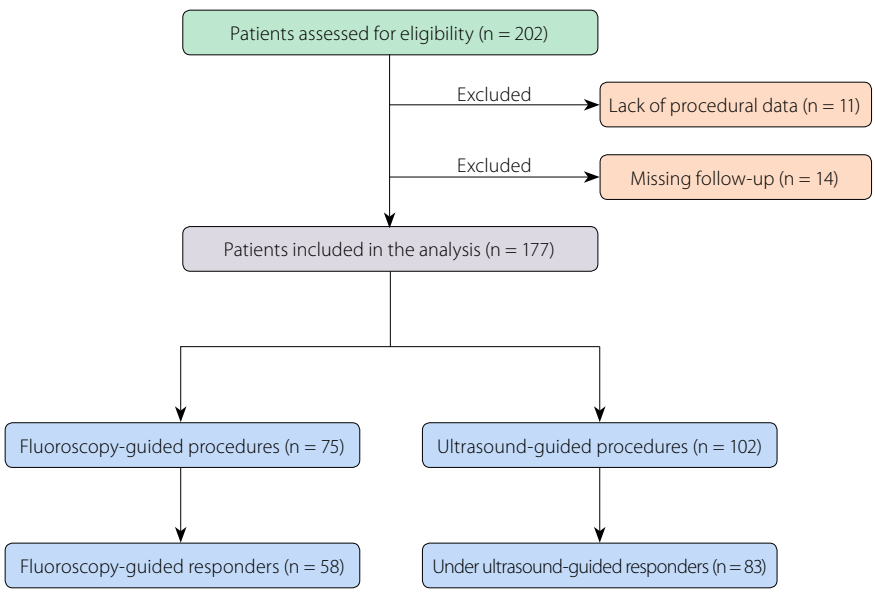

Figure 3 Study flowchart.

adjustment. Sensitivity analyses were performed to assess the robustness of the findings to missing data assumptions and included: (a) last observation carried forward (LOCF), applying all 177 patients at each time point, and (b) an all-visit completers analysis. *P* values were reported to three decimal places (< 0.001 reported as $p < 0.001$). Post-hoc power analysis indicated that the achieved sample size (FL = 75, US = 102; pooled SD ≈ 1.64) provided 80% power (α = 0.05) to detect an inter-group difference of approximately 0.70 NRS points (Cohen's d ≈ 0.43).

RESULTS

Of the 177 patients included in the study, 60 were male and 117 were female with a mean age of mean age of 53.47 ± 5.46 (range, 39 to 66) years. A total of 141 patients (79.7%) had data available at the three- and/or six-month follow-up, while 36 (20.3%) were lost to follow-up. Loss to follow-up was balanced between groups (US: n = 19; FL: n = 17). The flowchart is shown in Figure 3.

At baseline, the FL and US groups were comparable in age, sex, pain, disability, and analgesic use ($p > 0.05$ for all) (Table 1a). Procedural characteristics are summarized in Table 1b. The mean baseline NRS was 7.8 ± 1.0 and baseline NDI was 22.9 ± 4.8. As expected, FL exposure occurred only in FL (mean: 13.71 ± 2.32 shots). Compared to FL, US required fewer needle redirections per treated level and had a shorter procedure time ($p < 0.001$ for both). Minor periprocedural complications were more frequent in FL (30.7% *vs.* 11.8%, $p = 0.003$). Consistent with these findings, inter-group contrasts showed significant procedural differences favoring US: mean difference (FL-US) in needle redirections per level 2.20 (95% CI: 1.94 to 2.45) and in procedure time 5.78 min (95% CI: 5.23 to 6.32), while the risk of minor complications was higher with FL (RR=2.61, 95% CI: 1.39 to 4.90).

Clinical outcomes are shown in Table 2. At six weeks (n = 177), mean NRS and NDI were slightly lower in US than FL; however, the unadjusted inter-group differences were not significant (mean difference FL-US: NRS 0.17, 95% CI: −0.32 to 0.66, $p = 0.496$; NDI 0.39, 95% CI: −1.10 to 1.87, $p = 0.607$). At six weeks, monthly analgesic use (oral tablets/30 days) was 9.99 ± 4.65 in FL and 10.73 ± 4.36 in US (mean difference: FL-US

Table 1a. Baseline demographic and clinical characteristics by imaging guided (FL *vs.* US)

	FL (n = 75)		US (n = 102)		
Variables	%	Mean ± SD	%	Mean ± SD	*p*
Age (year)		52.81 ± 5.42		53.95 ± 5.47	0.124
Sex					
Female	68.0		64.7		0.767
Baseline NRS		7.68 ± 0.86		7.52 ± 1.11	0.317
Baseline NDI		22.40 ± 5.50		23.14 ± 5.18	0.210
Baseline analgesic use (tablets/month)		18.24 ± 4.18		18.93 ± 3.63	0.205

FL, fluoroscopy; US, under ultrasound; SD, standard deviation; NRS, Numeric Rating Scale; NDI, Neck Disability Index.

Table 1b. Procedural characteristics and inter-group contrasts

	FL			US				
Variables	n	%	Mean ± SD	n	%	Mean ± SD	*p*	Effect (95% CI)
Fluoroscopy shots	75		13.71 ± 2.32	0	NA	NA	-	-
Laterality (bilateral %)	75	26.7		102	26.5		1.000	RR 1.01 (0.61 to 1.65)
Three levels treated (%)	75	76.0		102	69.6		0.397	RR 1.09 (0.91 to 1.31)
Needle redirections per level	75		3.56 ± 1.02	102		1.36 ± 0.50	< 0.001	Mean difference (FL–US) 2.20 (1.94 to 2.45); d=2.88
Procedure time (min)	75		14.41 ± 2.24	102		8.64 ± 0.93	< 0.001	Mean difference (FL–US) 5.78 (5.23 to 6.32); d=3.56
Complications (any %)	75	30.7		102	11.8		0.003	RR 2.61 (1.39 to 4.90)

FL, fluoroscopy; US, under ultrasound; SD, standard deviation; CI, confidence interval. For continuous variables, the mean difference is FL-US with 95% CI (Welch). For binary variables, the effect is the risk ratio (FL/US) with 95% CI; *p*-values are from Pearson's χ^2 tests with continuity correction (Yates). Fluoroscopy shots are reported only for FL.

Table 2. Clinical outcomes with 95% confidence intervals and effect sizes

	FL		US				
Outcomes	n	Mean ± SD	n	Mean ± SD	Mean difference (95% CI)	*p*	Cohen's d
NRS (6 weeks)	75	4.60 ± 1.58	102	4.43 ± 1.69	0.17 (–0.32 to 0.66)	0.496	0.10
NRS (3 months)	58	3.12 ± 0.90	83	3.06 ± 0.83	0.06 (–0.24 to 0.36)	0.686	0.07
NRS (6 months)	58	3.36 ± 0.79	83	3.31 ± 1.32	0.05 (–0.30 to 0.40)	0.784	0.04
NDI (6 weeks)	75	14.72 ± 5.17	102	14.33 ± 4.60	0.39 (–1.10 to 1.87)	0.607	0.08
NDI (3 months)	58	8.72 ± 2.53	83	8.94 ± 2.40	–0.22 (-1.06 to 0.62)	0.612	–0.09
NDI (6 months)	58	9.19 ± 2.63	83	9.20 ± 2.55	–0.02 (–0.89 to 0.86)	0.973	–0.01
Analgesic use (6 weeks)	75	9.99 ± 4.65	102	10.73 ± 4.36	–0.74 (–2.10 to 0.62)	0.286	–0.17
Analgesic use (3 months)	58	6.07 ± 1.51	83	5.73 ± 1.59	0.33 (–0.19 to 0.86)	0.208	0.21
Analgesic use (6 months)	58	6.59 ± 1.34	83	6.16 ± 1.68	0.43 (–0.07 to 0.93)	0.094	0.28

FL, fluoroscopy; US, under ultrasound; SD, standard deviation; CI, confidence interval; NRS, Numeric Rating Scale (0-10); NDI, Neck Disability Index (0-50). Mean difference is FL–US (95% CI). *P*-values to three decimals (< 0.001 as $p < 0.001$). Cohen's d shown. Completers are available-case at each visit; details in Methods. Baseline analgesic use is reported as tablets per month.

–0.74, 95% CI: –2.10 to 0.62; $p = 0.286$). At three and six months (available-case: n=141 at each time point), unadjusted contrasts likewise remained null (e.g., six-month mean difference, FL-US: NRS 0.05, 95% CI: –0.30 to 0.40, $p = 0.784$; NDI –0.02, 95% CI: –0.89 to 0.86, $p = 0.973$).

The ANCOVA was adjusted for baseline NRS, age, sex, bilaterality, and number of treated levels, the adjusted six-week NRS means and the results were 4.56 (95% CI: 4.25-4.87) for FL and 4.46 (95% CI: 4.17-4.75) for US, yielding an adjusted difference (FL-US) of 0.10 (95% CI: –0.34 to 0.53; $p = 0.657$). A longitudinal MMRM showed no modality×visit interaction for NRS ($p > 0.5$) or NDI ($p > 0.3$), indicating parallel trajectories after covariate adjustment. Baseline characteristics were comparable between six-month completers (n = 141) and non-completers (n = 36) –age 53.5 ± 5.5 *vs.* 53.2 ± 5.2 years; NRS 7.53 ± 1.03 *vs.* 7.81 ± 0.95; NDI 22.8 ± 5.5 *vs.* 22.9 ± 4.8; male 33.3% *vs.* 36.1%; US 58.9% *vs.* 52.8% ($p \geq 0.135$ for all), supporting a Missing At Random (MAR) mechanism for the longitudinal models.

Complementary paired analyses showed significant intra-group improvements from baseline at each time point for both modalities. At six weeks, ΔNRS was 3.09 in US and 3.08 in FL (both $p < 0.001$), and ΔNDI was 8.80 and 7.68 ($p < 0.001$ for both). At three months, ΔNRS increased to 4.41 (US) and 4.50 (FL), with ΔNDI 13.94 (US) and 13.97 (FL) ($p < 0.001$ for all). At six months, benefits persisted (US ΔNRS 4.16; FL 4.26; US ΔNDI 13.67; FL 13.50; $p < 0.001$ for all). There were no significant inter-group differences in change at any time point (e.g., six-month Δ mean difference, FL–US 0.10, 95% CI: –0.27 to 0.48, $p = 0.83$; ΔNDI –0.17, 95% CI: –1.72 to 1.45, $p = 0.38$). Across secondary endpoints (NDI and monthly analgesic use at each visit), multiplicity control with Holm-Bonferroni left all inter-group differences non-significant.

Responder analyses were consistent: proportions achieving ≥ 50% reduction in NRS and ≥ 40% improvement in NDI were similar across modalities at 6 weeks (NRS 59.8% *vs.* 58.7%; NDI 52.0% *vs.* 50.7%), three months (NRS 79.5% *vs.* 77.6%; NDI 77.1% *vs.* 75.9%), and six months (NRS 73.5% *vs.* 75.9%; NDI 72.3% *vs.* 74.1%) (p > 0.05 for all). Likewise, risk-ratio estimates did not favor either modality (e.g., six-week NRS responder RR = 1.02, 95% CI: 0.85-1.21, $p = 0.66$; six-week NDI responder RR=1.03, 95% CI: 0.81-1.29, $p = 0.82$), with similarly null effects at three and six months.

In the LOCF sensitivity analyses including all 177 patients at each time point the direction and magnitude of effects were unchanged: intra-group improvements persisted and no inter-group differences emerged for NRS, NDI, or analgesic use (Supplementary Table 1). Longitudinal trends under the LOCF sensitivity approach are shown in Supplementary Figure 1. Given the retrospective design, these are reported as LOCF sensitivity (not intention-to-treat) analyses; findings were concordant with the available-case and MMRM results. Longitudinal trends in NRS, NDI, and monthly analgesic use across follow-up visits are illustrated in Figure 4.

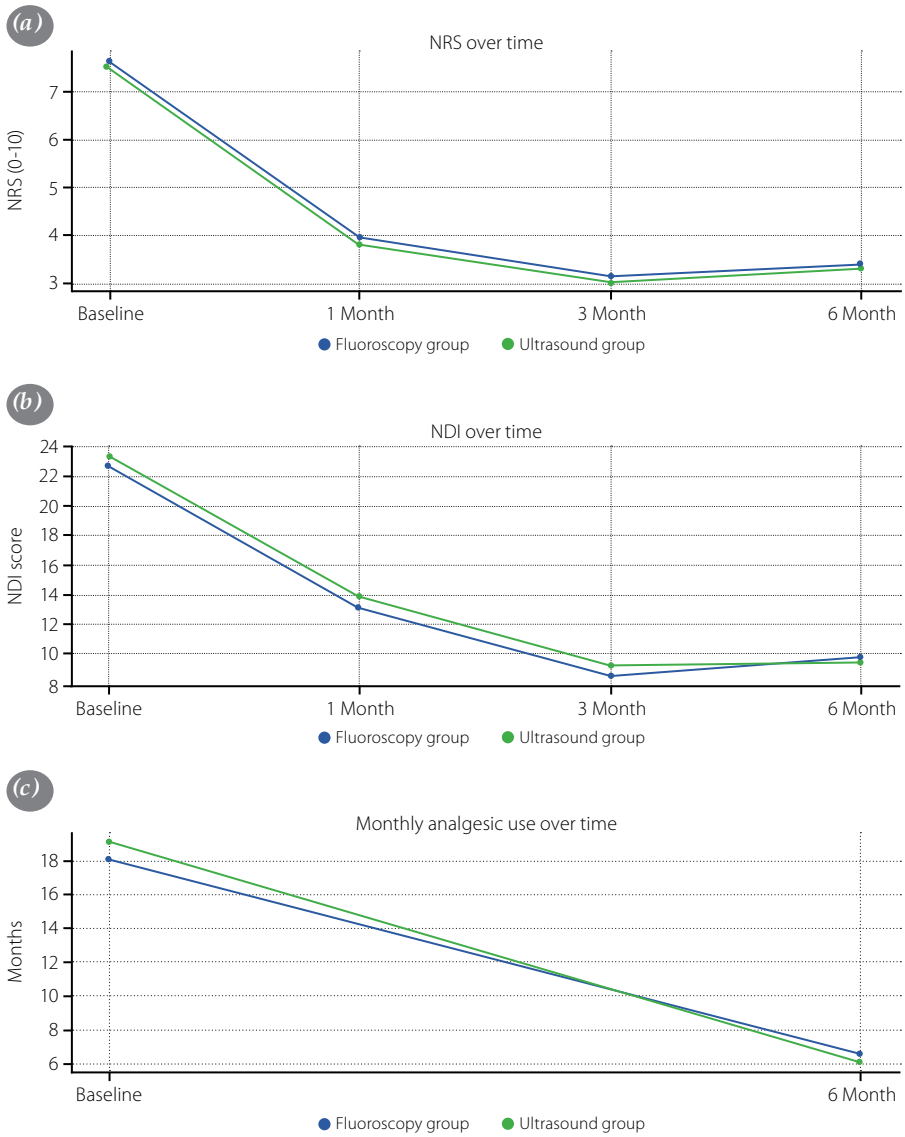

Figure 4. Longitudinal changes in **(a)** NRS, **(b)** NDI, and **(c)** monthly analgesic use from baseline to 6 months.

Values are presented as mean ± SD. Analyses include the whole cohort at 6 weeks (n = 177) and available-case data at 3 and 6 months (n = 141).

DISCUSSION

In the current study, we compared the PRF treatment of the cervical medial branch using US and FL-guided techniques in terms of efficacy, procedural features, and safety, examining these aspects in detail. Our study results showed that both methods had similar clinical effectiveness in terms of pain (NRS) and disability (NDI) scores. However, compared to FL-guided procedures, US-guided procedures had shorter procedure times and required less needle redirection. US-guided procedures also had a lower rate of minor complications. Based on these findings, the US-guided technique appears to offer significant procedural advantages along with comparable effectiveness.

On the other hand, although a post-hoc power analysis was performed in the present study, the clinical relevance of the observed inter-group difference should be interpreted in the context of the minimal clinically important difference (MCID). For chronic pain outcomes assessed using the NRS, an MCID of approximately 1.5 to 2.0 points is commonly reported in the literature.[17-19] In this study, the adjusted inter-group difference in six-week NRS was

slight (approximately 0.1 points), with confidence intervals well below the accepted MCID threshold. Therefore, even if a statistically significant difference had been observed, it would not have represented a clinically meaningful advantage of one imaging modality over the other. This finding supports the interpretation that US and FL guidance provide comparable clinical effectiveness with respect to pain relief.

Fluoroscopy-guided procedures have been used for many years and are now well standardized. Several studies also indicate that US-guided procedures are safer and more effective than landmark-based or FL-guided injections, especially in the cervical spine.[15,20,21] The current literature primarily evaluates these two imaging methods using medial branch blocks.[15] Our study may address the lack of research on the procedural feasibility of PRF treatment for cervical facet medial branches. It may suggest that US-guided procedures, which are less commonly used, are a viable option.

In PRF applications targeting the cervical medial branches, an average application time of four minutes is required for each segment. Under FL guidance, the needle is placed in the center of the articular pillar; however, due to two-dimensional imaging, verification and stimulation with the scope are required for each direction. Additionally, the proximity of the facet joints in some patients makes it technically challenging to treat them simultaneously at multiple levels. This can increase the time taken to place the needles and the number of FL-guided cervical medial branch PRF redirections required. To reduce this time, Siegenthaler et al.[21] described a thermal RF denervation method which was shorter and based on the anatomical localization of nerves. This method was performed under US guidance and was used to treat pain related to the cervical zygapophyseal joints. They noted in their studies that US nerve imaging performed before FL facilitated targeting and significantly reduces the total procedure time.

The out-of-plane US-guided approach enables sequential cannula placement at multiple target levels without requiring repositioning of the transducer.[16] This can significantly shorten the overall duration of RF procedures, as shown in our study. We did not record procedure costs, room turnover, or operator time beyond the procedure duration; future studies should measure these operational outcomes. In addition, the accuracy of FL is established, providing clarity of the bony structures. On the other hand, the literature also reports that FL-guided procedures, particularly those involving multiple levels, lead to significant radiation exposure.[22,23] This indicates that radiation exposure may be considerable in multi-level applications. In this respect, US has a better safety profile. These technical efficiencies may contribute to fewer periprocedural complications, greater post-procedural comfort, and reduced need for additional pharmacologic treatment. These findings are consistent with previous reports suggesting that improved technical execution can positively influence patient-reported outcomes.[15] Additionally, the absence of ionizing radiation during US-guided procedures enhances procedural safety for both patients and healthcare providers.

In patients with short neck morphology or a restricted acoustic window, the short-axis out-of-plane approach has been suggested to facilitate easier needle alignment and advancement by providing a steeper and shorter needle trajectory.[24,25] In our study, the short-axis out-of-plane approach was chosen for its practical applicability; no direct comparison with the in-plane technique was performed. This approach appeared to facilitate the placement of multiple RF cannulas without overlap and to shorten the procedure time. As the superiority of in-plane and out-of-plane methods is not clear, we recommend future studies comparing these approaches.

One of the most important clinical findings of this study is the statistically significant difference in the incidence of minor periprocedural complications between the FL and US-guided groups. All reported events were self-limiting and did not require additional treatment. This is one of the safety advantages of US imaging. The lower incidence of periprocedural events in the US-guided group may make US more preferable in patients at risk of bleeding (e.g., coagulopathy, vascular risk factors), particularly in outpatient settings. We suggest that fewer minor complications may translate into higher patient satisfaction, faster recovery, and reduced need for post-procedural monitoring. Taken together, the findings of this study confirm the technical feasibility of US for cervical medial branch PRF.

In individuals with chronic neck pain, persistent involvement of painful muscle groups may limit cervical range of motion over time, potentially exacerbating pain.[26] Therefore, isometric exercises targeting the cervical paraspinal muscles have been recommended for all patients, starting one week after the procedure in our study. Indeed, the

long-term efficacy of PRF has been documented in previous studies.[27] The six-month results obtained in our study may be related to the isometric exercise program or the neuromodulatory effect of the PRF treatment. This could be an effect that persisted after the procedure, with the use of analgesics remaining significantly low six months later.

The main strengths of our study include its relatively large sample size and strict inclusion criteria based on diagnostic medial branch block response. All eligible patients who met the diagnostic criteria were included, thereby minimizing selection-related confounders and enhancing generalizability. An experienced pain specialist performed all interventional procedures, and an orthopedic surgeon made patient referrals with a focus on spinal surgery. This structure supports both homogeneity in patient selection and standardization in application. Patient chart screening and data abstraction were performed by an independent physician who was not involved in the procedures or follow-up, thereby reducing the risk of selection and assessment bias. In addition, standardized RF protocols were used in both groups, with identical stimulation parameters, settings, and outcome time points, so that observed differences are more likely attributable to the imaging modality than to procedural variation.

On the other hand, due to the single-center, retrospective, non-randomized design, allocation to FL or US was determined pragmatically by equipment availability and logistical factors, which may have introduced selection bias and residual confounding despite adjustment for key covariates and comparable baseline characteristics between groups. Follow-up beyond six weeks was restricted to patients with available data, which may have increased the risk of attrition bias; however, loss to follow-up was balanced between groups, and sensitivity analyses using last observation carried forward yielded concordant results. As no a priori sample size calculation was performed, the post-hoc sensitivity analysis indicated that the study was powered to detect only moderate inter-group differences (approximately 0.70 NRS points at Week 6), and more minor effects cannot be excluded. Monthly analgesic consumption was recorded as total tablets per month without differentiation by drug class or dose, which limits direct comparability across analgesic types. In addition, the single-center, single-operator setting may limit generalizability, although procedural consistency was ensured. Analgesic use was patient-reported; the study was not powered to detect rare adverse events, and radiation dose, costs, and productivity outcomes were not assessed. Further multi-center, large-scale, prospective studies with randomized allocation and multiple operators are warranted to confirm these findings.

In conclusion, our study results indicate that US- and FL-guided PRF of the cervical medial branches offer comparable improvements in pain intensity, disability, and analgesic use. Ultrasound guidance may be associated with certain procedural advantages, including fewer needle redirections, shorter procedure time, and fewer minor periprocedural complications; however, there is no clinically meaningful differences in patient-reported outcomes between imaging modalities. These findings suggest that US guidance represents a feasible alternative to FL for cervical medial branch PRF in routine clinical practice. More importantly, PRF is not the standard neurotomy technique for facet joint-mediated pain, and the present results should, therefore, be interpreted within the context of PRF as a neuromodulatory, safety-oriented approach rather than a definitive ablative treatment. Future prospective, randomized-controlled studies are needed to define further the role of imaging modality and RF technique in this setting.

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Author Contributions

Ç.A., E.Y.: Concept/design, analysis and/or interpretation, literature review, references; Ç.A.: Data collection and/or processing, writing the article, critical review, supervision, materials.

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The authors declare that artificial intelligence (AI) tools were not used, or were used solely for language editing, and had no role in data analysis, interpretation, or the formulation of conclusions. All scientific content, data interpretation, and conclusions are the sole responsibility of the authors. The

authors further confirm that AI tools were not used to generate, fabricate, or 'hallucinate' references, and that all references have been carefully verified for accuracy.

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