Observational Study

Ultrasound-guided Pulsed Radiofrequency at the C2 Level for Cervicogenic Headache: Targeting the Greater Occipital Nerve

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Background: Cervicogenic headache is a secondary headache disorder caused by cervical spine dysfunction, often associated with neck pain. Among the various treatment options, peripheral nerve blocks targeting the greater occipital nerve are commonly used, with pulsed radiofrequency emerging as a promising therapeutic intervention.

Objectives: Our study aimed to evaluate the clinical efficacy and safety of ultrasound-guided greater occipital nerve pulsed radiofrequency treatment at the second cervical vertebrae (C2) level in patients with cervicogenic headache. Specifically, we investigated changes in headache duration, intensity, frequency, analgesic use, and patient satisfaction.

Study Design: Single-center, prospective, observational cohort study.

Setting: Tertiary referral center.

Methods: Our study included 43 patients diagnosed with cervicogenic headache according to the International Classification of Headache Disorders Third Edition criteria. A diagnostic greater occipital nerve block was performed on all patients; 34 exhibited a positive response and subsequently received greater occipital nerve pulsed radiofrequency treatment. Data were analyzed by comparing the pretreatment and posttreatment results.

Results: A total of 32 patients were included in our final analysis. Their mean (SD) age was 55.8 (10.9) years. Significant reductions in headache duration, intensity, and frequency were observed at both the first and third posttreatment months compared to baseline ($P < 0.001$). Visual Analog Scale scores and analgesic use also showed significant reductions. No statistically significant difference was observed between the first and third posttreatment months regarding these outcomes, and the Global Perceived Effect score remained stable during this period ($P = 0.058$).

Limitations: Our study has several limitations that should be considered when interpreting the findings. While the sample size was determined using G*Power (Heinrich-Heine-Universität Düsseldorf), our study population's relatively small size may affect the generalizability of the results. Furthermore, the inclusion of patients with a history of both cervicogenic headaches and migraines may have introduced diagnostic complexity. Lastly, the relatively short follow-up period may not fully capture the long-term effects of the intervention.

Conclusion: Our study demonstrates that, in patients who respond to a diagnostic block, ultrasound-guided greater occipital nerve pulsed radiofrequency treatment at the C2 level effectively reduces the duration, severity, and frequency of cervicogenic headaches, while decreasing analgesic use. These effects appear to persist for at least 3 months, though further research is required to evaluate long-term outcomes.

Key words: Cervical pain, headache, pulsed radiofrequency treatment, secondary headache disorders, spinal nerves, Visual Analog Scale, ultrasonography, interventional

Trial Registration: Institutional Review Board (E1-23-3686/07.06.2023) and ClinicalTrials.gov (NCT06764433)

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Cervicogenic headache (CHA), according to the International Headache Society's International Classification of Headache Disorders Third Edition criteria, is defined as a secondary headache caused by a disorder in the cervical spine or its components, including bones, discs, and/or soft tissue elements, typically accompanied by neck pain (1). This type of headache is often considered referred pain resulting from the irritation of cervical structures innervated by the upper cervical nerves (C1–C3). CHA is estimated to account for approximately 15%–20% of chronic headache cases (2).

For a diagnosis, there must be at least 2 causal evidence criteria: the headache develops temporally in relation to the onset or resolution of the cervical disorder, the reduction of cervical range of motion with worsening of the headache by provocative maneuvers, or the resolution of the headache after blocking cervical structures. Additionally, clinical and/or imaging evidence of the cervical disorder causing the headache is required (1).

The most common pain source is a degenerative change in the upper cervical spine (3). However, imaging findings in the upper cervical spine are also common in patients without headache, and while these findings may suggest a diagnosis, they do not provide definitive causal evidence (1).

Imaging studies are helpful for excluding secondary causes (4). No specific radiological changes are found with magnetic resonance imaging (5,6).The clinical presentation of CHA is characterized by unilateral, non-throbbing, variable duration, or continuous occipital pain, often originating from the neck. When attacks are prolonged or severe, the pain may radiate to the contralateral side. While the headache typically radiates from the occipital region forward, neck pain often radiates to the shoulder and arm. Typical attacks can be triggered by uncomfortable posture or pressure on sensitive areas of the neck (7).

Given the complex etiology of CHA, treatment typically requires a multidisciplinary approach, combining pharmacological therapy, physical therapy, and interventional pain management techniques (8). Interventional procedures generally aim to block the transmission of pain signals from the upper cervical nerves, targeting the potential cervicogenic sources of pain (9,10). These include peripheral nerve blocks targeting the greater and lesser occipital nerves arising from the dorsal branches of C2 and C3. These blocks are used both diagnostically and therapeutically (11).

The rationale for using a greater occipital nerve block (GONB) is based on evidence that sensory inputs from cervical and trigeminal fibers converge in the trigeminal nucleus caudalis, supporting the effectiveness of GONB in relieving headache symptoms (12). That is, the block can both directly target the source of pain and modulate the interaction between cervical and trigeminal nerves, potentially reducing headache severity and contributing to treatment effectiveness (13).

Preliminary findings suggest that GONBs may be beneficial for treating CHA. Additionally, treatment success may be improved by combining proximal GONBs, repeated blocks, or blocking other cervical terminal branches of GON (14). One significant advantage of ultrasound guidance is the ability to perform a proximal occipital nerve block at the C2 level. A prospective randomized controlled trial showed that ultrasound-guided GONBs at the C2 level were more effective and provided better pain control compared to anatomical landmark-based upper nuchal line GONBs in patients with CHA (15).

Pulsed radiofrequency (PRF) has emerged as a potential treatment for managing neuropathic pain associated with peripheral nerves or cervical nerve roots. This method provides temporary neuromodulation of pain transmission in targeted nerves without causing permanent damage to neuronal structures or surrounding tissues (16). A study comparing greater occipital nerve pulsed radiofrequency (GONPRF) with GONB for CHA reported long-term pain improvement in the PRF group (17). A recent systematic review investigating the effectiveness of interventional treatment strategies for CHA emphasized that PRF treatment provided better safety outcomes compared to radiofrequency ablation, although current evidence remains limited (8).

The aim of our study was to evaluate the clinical efficacy and safety of ultrasound-guided PRF treatment of the GON at the C2 level for managing CHA.

Methods

Our study was conducted at the Pain Clinic of Ankara Bilkent City Hospital from June 2023 through March 2024, following approval from the Clinical Research Ethics Committee of Ankara Bilkent City Hospital (E1-23-3686/07.06.2023). Written informed consent was obtained from all patients. Our study complied with the 2013 Declaration of Helsinki. The trial was registered at ClinicalTrials.gov (NCT06764433).

Patient Selection

A total of 51 patients diagnosed with CHA according to International Classification of Headache Disorders Third Edition criteria were evaluated. Eight were excluded for not meeting the inclusion criteria. Nine patients with < 50% improvement after a diagnostic GONB were also excluded. The remaining 34 patients (≥ 50% response) received GONPRF treatment. Two were excluded due to loss to follow-up; thus, 32 patients completed the study (Fig. 1).

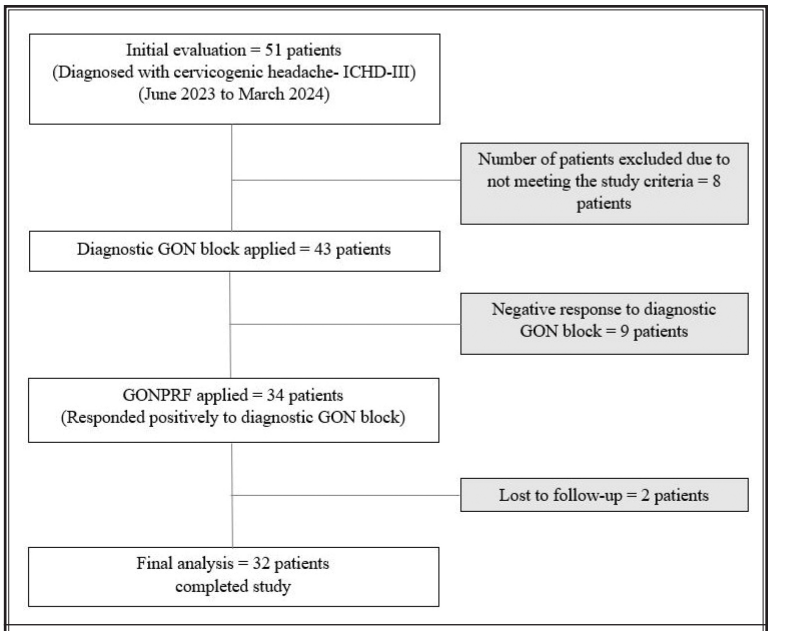

Fig. 1. *Flow chart of the study.*

Sample Size Calculation

According to the G*Power analysis technique, the lower limit of the sample size, calculated based on the percentage error of the temporal variation of the Visual Analog Scale (VAS) value from the reference study, was determined to be 22. In the reference study, based on Table 1, when considering the time-dependent values of Group B, the total required sample size for testing the difference between baseline and the third time point, with a Type I error of 5% and a Type II error of 1%, was calculated to be 22 patients (17). However, to account for potential data loss and patient dropout, a larger number of patients were included in the study. The sample size was determined through power analysis using G*Power 3.1.9.2 software (Heinrich-Heine-Universität Düsseldorf), ensuring statistical power was maintained and reliable results were achieved.

Table 1. *The clinical features of patients with cervicogenic headache.*

	Baseline	First Posttreatment Month	Third Posttreatment Month
	Median (IQR)		
Medications in case of headache n (%)			
None	1 (3.1)	5 (15.6)	5 (15.6)
NSAIDs	25 (78.1)	18 (56.3)	18 (56.3)
Acetaminophen	10 (31.3)	8 (25.0)	9 (28.1)
NSAIDs and acetaminophen	-	1 (3.1)	2 (6.3)
Opioids	-	-	-
Triptans	-	-	-
Ergotamines	-	-	-
Topical agents	5 (15.6)	4 (12.5)	4 (12.5)
Other	-	-	-
Side effects of medications n (%)	7 (21.9)	-	-
Duration of side effects (minutes)	60.0 (50.0)	-	-
Side of GON block/PRF n (%)			
Bilateral	5 (15.6)	-	-
Right	10 (31.3)		
Left	17 (53.1)		

* IQR: interquartile range, NSAID: nonsteroidal anti-inflammatory drug, GON: greater occipital nerve, PRF: pulsed radiofrequency.

Inclusion Criteria

The study included patients who met the following criteria:

- Age > 18 years,
- Diagnosis of CHA
- Cranial and cervical imaging performed
- Experienced ≥ 5 headache days per month
- Insufficient relief from pharmacological treatments/physical therapy
- Capable of understanding and consenting to treatment
- Able to adhere to the treatment protocol.

Exclusion Criteria

The following exclusion criteria were applied:

- Secondary headache disorders other than CHA
- Primary headache disorders with active, frequent attacks

- Symptoms or signs of cervical nerve root irritation or spinal stenosis
- Craniocervical defects, or some comorbidities (e.g., uncontrolled hypertension, intracranial lesions, malignancy)
- Local/systemic infections, pregnancy, allergy to local anesthetics
- Bleeding or clotting disorders, or use of oral anticoagulants
- Nonpharmacological treatments within the last 6 months, or recent cranial/cervical surgery
- Conditions that could affect treatment adherence or evaluation (e.g., psychiatric disorders, dementia).

Procedure

Prior to the intervention, routine laboratory tests were conducted, and peripheral vascular access was established. All procedures were performed in a sterile operating room environment, adhering to standard anesthesia monitoring protocols.

Diagnostic GONB

For the ultrasound-guided GONB, patients were positioned prone with their necks flexed. Anatomical landmarks, including the obliquus capitis inferior muscle and the bifid spinous process of the C2 vertebra, were identified. A linear ultrasound probe (Toshiba, Aplio 500, Toshiba Medical) was placed transversely over the occipital prominence and advanced caudally to visualize the single spinous process of C1 and the bifid spinous process of C2. The probe was then laterally shifted to visualize the obliquus capitis inferior muscle and semispinalis capitis muscles, where the GON appeared as an oval, hypoechoic structure between the obliquus capitis inferior muscle and the semispinalis capitis muscles (Fig. 2). Using the in-plane technique, a 22G spinal needle was advanced from lateral to medial toward the GON with 2 mL of 0.5% bupivacaine injected into the target side.

GONPRF

For GONPRF, the same technique described above was used for identification under ultrasound guidance. A 22G RF cannula (5 cm in length with a 5 mm active tip) and RF electrode were positioned adjacent to the GON using an in-plane, lateral-to-medial approach. Sensory stimulation (below 0.3 V) was applied to elicit paresthesia or tingling in the occipital region, confirming correct placement. PRF was then delivered at 45 V, with a frequency of 5 Hz, pulse width of 5 milliseconds, and a temperature not exceeding 42°C for 360 seconds, using an RF generator (NeuroTherm NT1100).

Postprocedure Monitoring

After the GONB or PRF, patients were monitored in an observation room for at least one hour. A general and neurological evaluation was performed prior to discharge.

Treatment Side

For patients with consistent unilateral pain, the intervention was performed on the symptomatic side only. In cases of bilateral pain, the procedures were performed bilaterally.

Measurement and Data Collection

To evaluate the clinical effectiveness of GONPRF treatment, several outcome measures were assessed at predefined time points before and after the intervention. These included:

- Headache intensity, measured using an 11-point VAS, where 0 indicates no pain and 10 represents the most severe pain imaginable
- The number of headache days per month
- The number of days per month with analgesic use including acetaminophen, nonsteroidal anti-inflammatory drugs, combination analgesics, and opioid;
- The Global Perceived Effect (GPE) score, which reflects the patient's subjective perception of change in their primary complaint (18).

The GPE was assessed using a 7-point Likert-type scale with percentage-based interpretations for clarity.

7 = Very much improved (≥ 75% improvement)
6 = Much improved (50%–74% improvement)
5 = Slightly improved (25%–49% improvement)
4 = No change (0%–24% change)
3 = Slightly worsened (25%–49% worsening)
2 = Much worsened (50%–74% worsening)
1 = Very much worsened (≥ 75% worsening)

To ensure accurate data collection, patients were provided with a structured Headache Follow-up Form, given instructions on how to complete it, and asked to fill it out regularly throughout the follow-up period. Any adverse events or complications related to the procedure were also documented to evaluate treatment safety.

Patients completed the Headache Follow-up Form

starting from at least one month pretreatment and continued throughout the study period. This form included detailed information on headache onset, duration, intensity (VAS), pain localization, frequency, and analgesic use.

Our Study Follow-up Form, which included key clinical parameters, was filled out by specialist physicians at the pain clinic. During the initial visit, demographic information, comorbidities, medications, history of craniospinal surgery or trauma, imaging results, and CHA characteristics were recorded.

According to our clinical protocol, patients exhibiting a ≥ 50% reduction in VAS score a following diagnostic GONB proceeded to PRF at the third visit (1–2 weeks later). Follow-up assessments were performed at the first and third months post GONPRF.

Follow-up evaluations were conducted at the first and third posttreatment months; including changes in headache characteristics and treatment satisfaction were recorded.

Side Effects and Complications

During and after both the GONB and GONPRF procedures, patients were closely monitored for any adverse events, side effects, or complications. The nature, duration, and any required interventions for these events were carefully documented.

Statistical Analysis

The recorded data were analyzed using the IBM SPSS Statistics 27.0 (IBM Corporation). Normality of the numerical data distribution was assessed using the Shapiro-Wilk test. Normally distributed continuous variables are presented as mean ± SD, while nonnormally distributed variables are reported as median and interquartile range (IQR). Qualitative data are expressed as frequencies and percentages.

For repeated numeric variables, the Wilcoxon signed-rank test was used for comparisons. When more than 2 measurements were available, the Friedman test was applied. Categorical variables were compared using McNemar's test for 2 repeated variables and Cochran's Q test for more than 2 repeated variables.

A 95% CI was used, with a margin of error set at 5%. A P value < 0.05 was considered statistically significant.

Results

Demographic and Clinical Characteristics

The demographic and clinical characteristics of the patients are summarized in Table 2. A total of 32 patients were included in the analysis. Their mean age was 55.8 (10.9). Eighteen (56.3%) were women. The median CHA duration was 24.0 (IQR, 36.0) months.

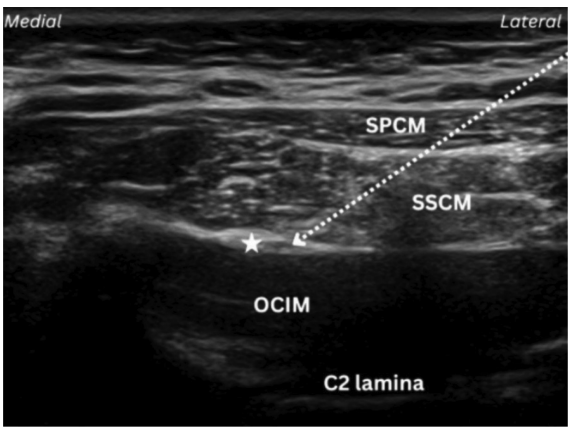

Fig. 2. *Ultrasound image of the greater occipital nerve (GON) at the C2 level.*
SPCM: splenius capitis muscle; SSCM: semispinalis capitis muscle; OCIM: obliquus capitis inferior muscle; white dashed line: needle trajectory; star: GON; C2 lamina: lamina of the axis vertebra

Four patients (12.5%) had a history of craniocervical trauma, and one patient (3.1%) had previously undergone surgery for a cervical disc herniation. Eight patients (25%) reported infrequent episodic migraine. Headache was unilateral in 27 patients (84.4%). All patients underwent cervical magnetic resonance imaging, and most also had cranial magnetic resonance imaging. Cervical imaging revealed varying degrees of degenerative or discogenic changes. The clinical features of CHA are detailed in Table 1.

Headache Duration

The duration of headache attacks (hours) significantly decreased at both the first posttreatment month (3.0; IQR, 3.0) and the third posttreatment month (3.0; IQR, 2.8) compared to baseline (6.5; IQR, 6.0) (P < 0.001 for both). No significant difference was found between the first and third posttreatment months (P = 0.132).

VAS Scores

The mean VAS scores significantly decreased at the first posttreatment month (4.0; SD, 1.0) and the third posttreatment month (4.0; SD, 1.0) compared to baseline (6.0; SD, 2.0) (P < 0.001 for both). However, no significant difference was observed between the first and third posttreatment months (P = 0.058) (Fig. 3).

Table 2. *Sociodemographic and clinical data of the patients (n = 32).*

Age (mean ± SD)	55.8 ± 10.9
Gender n (%)	
Women	18 (56.3)
Men	14 (43.8)
Education n (%)	
Illiterate	3 (9.4)
Primary school	15 (46.9)
Intermediate school	2 (6.3)
High school	4 (12.5)
University	8 (25.0)
Comorbidities n (%)	
None	19 (59.4)
HT	10 (31.3)
Diabetes	3 (9.4)
CAD	1 (3.1)
COPD	1 (3.1)
Hypothyroidism	4 (12.5)
PTR history n (%)	22 (68.8)
Craniocervical surgery history n (%)	1 (3.1)
History of trauma n (%)	4 (12.5)
Cranial MRI n (%)	
Not performed	2 (6.3)
Normal	25 (78.1)
Anormal findings	5 (15.6)
Primary headache n (%)	
Migraine	8 (25.0)
TTHA	-
Others	-
Duration of CHA (months)	24.0 (36.0)
Side of CHA n (%)	
Bilateral	5 (15.6)
Right	10 (31.3)
Left	17 (53.1)

HT: hypertension, CAD: Coronary artery disease, COPD: chronic obstructive pulmonary disease, PTR: physical therapy rehabilitation, MRI: magnetic resonance imaging, TTHA: tension-type headache, CHA: cervicogenic headache.

Most Severe VAS Score

The most severe VAS scores were significantly reduced in both the first and third posttreatment months compared to baseline ($P < 0.001$ for both). Additionally, scores were significantly lower in the first posttreatment month compared to the third posttreatment month ($P < 0.001$).

Headache Frequency

The number of days with headaches significantly decreased in both the first and third posttreatment months compared to baseline ($P < 0.001$ for both). No significant difference was found between the first and third posttreatment months ($P = 0.319$). The median number of days with headache during follow-up is presented in Fig. 4.

Headache Severity

Mild Headaches (VAS < 5): The number of days with mild headaches significantly decreased in both the first and third posttreatment months compared to baseline ($P < 0.001$ for both). No significant difference was found between the first and third posttreatment months ($P = 0.295$). Severe Headaches (VAS ≥ 5): The number of days with severe headaches significantly decreased in both the first and third posttreatment months compared to baseline ($P < 0.001$ for both). However, more days with severe headaches were reported in the third posttreatment month compared to the first posttreatment month ($P < 0.01$).

Analgesic Use

The median number of days with analgesic use significantly decreased in both the first (2.0; IQR, 4.0) and third posttreatment months (5.0; IQR, 5.8) compared to baseline (10.0; IQR, 10.8) ($P < 0.001$ for both). However, there was an increase in the number of analgesic use days in the third posttreatment month compared to the first posttreatment month ($P < 0.01$).

GPE Score

GPE scores were similar in the first and third posttreatment months ($P = 0.058$). Comparisons of pain levels, GPE scores, and clinical features during follow-up are presented in Table 3.

Side Effects

No significant or persistent side effects related to GONPRF were observed. Mild and transient side effects occurred in 7 patients (22%), including dizziness, lightheadedness, nausea, drowsiness, and headache.

Discussion

Our study evaluated the effectiveness of ultrasound-guided C2-level GONPRF treatment in managing CHAs. The findings indicate that GONPRF treatment significantly reduced headache duration, intensity, and frequency, and also substantially decreased in patients who responded positively to diagnostic GONBs. Notably, significant improvements were observed within the first posttreatment month, suggesting that GONPRF can provide rapid relief. However, most improvements were observed within the first posttreatment month, with no statistically significant change between the

first and third posttreatment months.

While the number of days of mild headaches remained constant, the number of days with severe headaches and analgesic use increased at posttreatment month 3. These findings suggest that GONPRF may provide longer-lasting relief for mild symptoms, whereas severe headaches may involve more complex mechanisms, leading to variable outcomes over time. The less pronounced changes observed in VAS scores in patients with mild headaches might be attributed to a ceiling effect stemming from their lower baseline pain levels or limitations related to sample size. A ceiling effect is a statistical construct that describes the clustering of a patient's scores toward the upper limit of a scale. This situation means that the measurement instrument insufficiently measures variance among high scores and limits its discriminatory power (19). Further studies are needed to evaluate long-term efficacy and to explore additional strategies for maintaining treatment success.

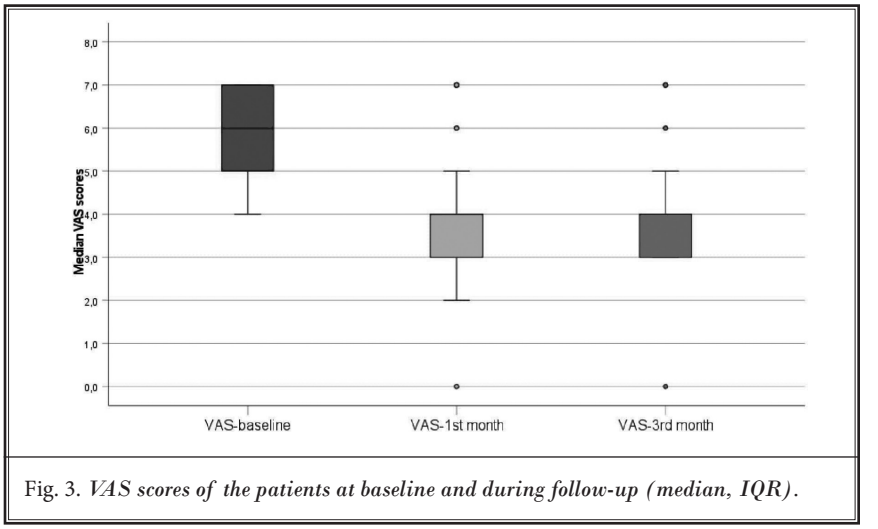

Fig. 3. *VAS scores of the patients at baseline and during follow-up (median, IQR).*

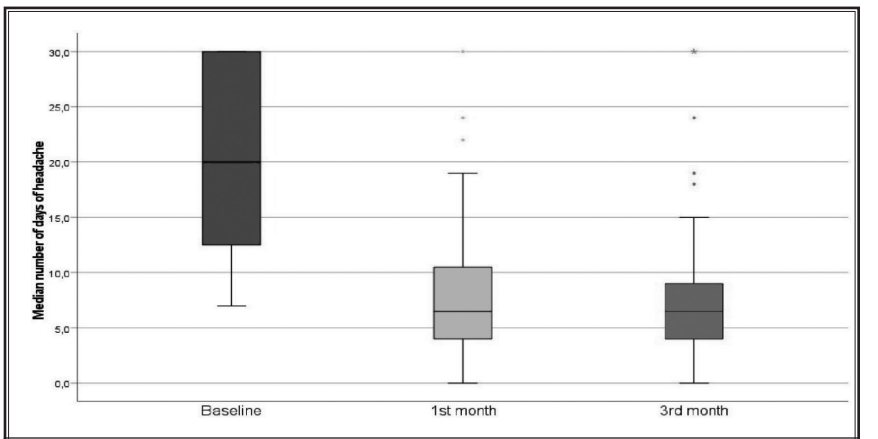

Fig. 4. *The median number of days of headaches of the patients at baseline and during follow-up.*

Another key finding of our study is the critical role diagnostic GONBs play in selecting appropriate patients. Among 43 evaluated patients, those achieving ≥ 50% pain reduction after the diagnostic block proceeded to GONPRF. This allowed for timely, targeted treatment without prolonged observation, consistent with evidence-based protocols (20). In clinical practice, ≥ 50% pain relief following a diagnostic block is a recognized criterion to proceed with PRF. Application of PRF to the occipital nerves after a positive block has demonstrated significant benefits in chronic headache (17,21). This prognostic use aids in confirming a diagnosis, predicting response, and avoiding unnecessary interventions. A timely neuromodulatory approach, it disrupts ongoing nociceptive input in line with chronic headache management strategies.

In our study, only mild and transient side effects associated with diagnostic GONBs and GONPRF treatment were observed, indicating that GONPRF offers a safe treatment option without serious adverse effects. This supports using GONPRF as a safe and viable treatment approach.

Previous studies have reported a reduction in mean pain intensity scores of approximately 50% after occipital nerve blocks, with this effect lasting for several weeks (22–25). It has also been thought that repeated injections may provide longer-lasting pain relief (8,26). Moreover, since only transient local pain was reported in a few patients, the procedure was generally considered safe. A systematic review of occipital nerve blocks for CHA concluded that GONBs are effective, safe, low-

Table 3. *Changes in headache characteristics and Global Perceived Effect (GPE) during follow-up.*

	Baseline	First Posttreatment Month	Third Posttreatment Month	*P*
	Median (IQR)			
Headache attacks duration (hours)	6.5 (6.0)	3.0 (3.0)	3.0 (2.8)	< 0.001[a]
VAS score	6.0 (2.0)	4.0 (1.0)	4.0 (1.0)	< 0.001[a]
Most severe VAS score	8.0 (1.0)	5.0 (2.0)	6.0 (1.8)	< 0.001[a]
Number of headaches days per month	20.0 (17.8)	6.5 (6.8)	6.0 (6.3)	< 0.001[a]
Number of days with mild headaches (VAS < 5)	9.5 (16.8)	5.5 (6.8)	5.0 (5.0)	< 0.001[a]
Number of days with severe headaches (VAS ≥ 5)	6.0 (3.8)	0.5 (2.0)	1.0 (3.5)	< 0.001[a]
Number of days with analgesic use per month	10.0 (10.8)	2.0 (4.0)	5.0 (5.8)	< 0.001[a]
GPE score	-	6.0 (2.0)	6.0 (2.0)	0.058[b]

[a] Friedman test, [b] Wilcoxon signed rank test, IQR: Interquartile range, VAS: Visual Analog Scale

cost, and reproducible, although the evidence is limited (27).

A study was conducted to measure neurophysiological responses related to the nociceptive blink reflex before and after occipital nerve block in healthy individuals without headache (13). The results indicated a functional connection between the sensory occipital segments at C2 and the ophthalmic branch of the trigeminal nociceptive system. These findings suggest that occipital nerves have a stimulating effect on trigeminal circuits, which can be reduced through anesthetic blockade (13). Therefore, modulation of the GON in CHAs may help prevent the spread and intensity of the headache. The efficacy of blocks performed at the C2 level supports the possible mechanism explaining CHAs, which involves the connection between the cervical nerves and the trigeminovascular system. However, the exact role of trigeminovascular activation in CHA remains unclear (28).

Lauretti et al (24), in a randomized, double-blind study, demonstrated that GONBs performed at the C2 spinous process level using a fluoroscopy-guided suboccipital compartment technique provided more effective and longer-lasting analgesia compared to the traditional GONB performed at the superior nuchal line. They attributed the increased efficacy of C2-level GONBs to the closer proximity of the drug to the dorsal ganglia. Similarly, another study comparing ultrasound-guided GONBs at the C2 vertebral level with landmark-based GONBs at the superior nuchal line reported more favorable clinical outcomes for C2-level GONBs in patients with occipital neuralgia or CHA (15). Consistent with the findings of previous studies, the results of our investigation also demonstrate that ultrasound-guided GONPRF at the C2 level is an effective treatment method in the early phase. Our study provides valuable insights into the efficacy and procedural aspects of GONPRF, evaluating its effects in a broader patient population.

A recent narrative review on peripheral nerve blocks for headache disorders reported limited evidence supporting the positive effects of GONBs for CHA. However, it was suggested that proximal GONBs, repeated blocks, or combinations of GONBs with other cervical terminal branch blocks might yield better results (14).

PRF is an innovative neuromodulation-based approach for chronic pain management, shown to affect multiple biological pathways (29). PRF alters pain signaling and synaptic transmission with minimal tissue damage, regulating neurotransmitter and postsynaptic receptor functions (16, 30). However, it should be noted that the effects of PRF may be shorter lasting compared to radiofrequency ablation, and repeated applications may be necessary (31).

In a randomized study conducted by Gabrhelík et al (17), it was reported that in the treatment of refractory CHAs, patients treated with GONPRF and GONBs showed significant reductions in pain severity and analgesic use. Furthermore, pain improvement lasted up to 9 months in the GONPRF group, and more than 50% improvement in GPE scores was observed in most patients. The study concluded that both GONBs and GONPRF treatments are effective, safe, and easily repeatable in managing refractory CHAs (17). Similarly, the results of our study showed similar improvements in pain intensity, analgesic use, and GPE scores despite differences in GONPRF application technique and duration. However, it should be considered that the effectiveness of GONPRF may decrease over time, suggesting that repeated applications may be required.

Limitations

Our study has several limitations that should be considered when interpreting the findings. First, although the sample size was determined using G*Power, the single-center, prospective, observational cohort design and relatively small number of patients may limit the generalizability of the results.

Additionally, a ceiling effect may have occurred for days classified as mild headache due to the already low baseline pain levels, which could have restricted the ability to detect further improvements. Another important limitation is the coexistence of CHA and migraine. There are reports that a subset of patients diagnosed with CHA may also fulfill the ICHD-3 diagnostic criteria for migraine. For instance, one study reported that 30% of patients with CHA met migraine criteria (32). Similarly, 25% of the patients in our study had a history of infrequent episodic migraine; however, their primary concern was CHA; they reported being able to clearly differentiate migraine attacks from CHA episodes. Nevertheless, the coexistence of both headache types may complicate a diagnosis and treatment planning.

Finally, the relatively short follow-up duration may have limited our ability to fully assess the long-term effectiveness and sustainability of the treatment. Longer follow-up periods and multicenter studies are needed to provide a more comprehensive evaluation of this treatment's efficacy and clinical relevance.

Conclusion

In conclusion, ultrasound-guided GONPRF treatment at the C2 level appears to be an effective and safe option for managing cervicogenic headache. It may be particularly suitable for patients who respond positively to diagnostic GONBs. Nevertheless, further large-scale and long-term studies are warranted to assess the sustained efficacy of this treatment. In clinical practice, diagnostic GONBs play a key role in identifying appropriate candidates for GONPRF and may help optimize treatment outcomes.

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Author Contributions

SD, SC: Conception and design of the study, study registration, data collection, manuscript writing, manuscript editing, and final approval of the manuscript.

GB, US, AC: Study design, data analysis, and final approval of the manuscript.

EYA, SS: Study design, manuscript editing, and final approval of the manuscript.

SD, SC, EYA: Data analysis, manuscript editing, and final revisions.

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