Observational Study

A Novel Ultrasonographic Method to Quickly and Accurately Access the C2 Dorsal Root Ganglion

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Disclaimer: L. He and W. Zhao contributed equally to this work. L. Yang and Z. Guan contributed equally to this work. There was no external funding in the preparation of this article.

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

Article received: 03-20-2024
Revised article received: 03-27-2027
Accepted for publication: 05-23-2024

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Background: Occipital neuralgia manifests as pain in the cutaneous distribution of occipital nerves, with the greater occipital nerve stemming from the C2 spinal nerve and the lesser occipital nerve originating from the C2 and C3 spinal nerves. While pulsed radiofrequency ablation of the C2 dorsal root ganglion (DRG) is an effective treatment for refractory occipital neuralgia, accessing the C2 DRG remains a clinical challenge even under fluoroscopic guidance.

Objective: We aimed to develop an ultrasonographic method for quickly and accurately accessing the C2 DRG.

Study Design: This is a prospective, observational cohort study.

Setting: Our study was conducted in the Department of Pain Management, Xuanwu Hospital, Capital Medical University, Beijing, China.

Methods: Unlike the C3-C8 foramina, which are ventral to the corresponding facet joints, the C2 foramen is positioned more posteriorly, dorsal to the C1-C2 atlantoaxial joint and longitudinally aligns with the cervical facet joints of C2-C3 and C3-C4. This unique anatomical feature allowed us to rapidly identify the C2 foramen in the sonographic longitudinal-axis view, what we call the "Stage-light Sign." Further exposure of the C2 DRG in the oblique-axis view we call the "Turtle Sign." The following procedural parameters were prospectively obtained: the time required to identify the C2 DRG target, the time needed to reach the target from the point of skin puncture, the number of puncture attempts required to reach the target, and the minimum sensory testing voltage to evoke paresthesia responses in the cutaneous occipital nerve distributions. Clinical outcomes were assessed by serial pain severity using the Numeric Rating Scale at baseline and up to 3 months post the C2 DRG pulsed radiofrequency ablation procedure.

Results: The correct placement of the needle tip was initially confirmed with fluoroscopy, with the injected contrast medium distributed along the C2 spinal nerve. Importantly, electrical sensory stimulation elicited paresthesia in the headache area in all patients, with the required voltage being 0.35 ± 0.02 V. Furthermore, treatment outcomes supported the correct needle tip position, as pulsed radiofrequency ablation treatment led to sustained pain reduction. It took 36.2 ± 2.2 seconds to obtain the final "TurtleSign" view of the C2 DRG. Once the target was identified, it required a single puncture attempt to reach it, with a duration of 36.3 ± 2.5 seconds from puncturing the skin to reaching the target.

Limitation: We only followed patients for up to 3 months postprocedure.

Conclusion: We have developed an ultrasonographic method to quickly and accurately access the C2 DRG, which has the potential to greatly facilitate treating the C2 DRG for managing occipital neuralgia.

Key words: Occipital neuralgia, ultrasound, C2 dorsal root ganglion, C2 foramen, pulsed radiofrequency ablation, longitudinal-axis view, oblique-axis view, needle insertion

Pain Physician 2024: 27:E927-E935

Occipital neuralgia is characterized by pain in the cutaneous distribution of 3 occipital nerves: the greater occipital nerve (GON), lesser occipital nerve (LON), and third occipital nerve (TON) (1). The GON innervates the skin on the back of the scalp up to the vertex of the skull, the LON innervates the scalp in the lateral region of the head behind the ear and the cranial surface of the ear, and the TON provides cutaneous innervation of the skin below the superior nuchal line (2). The GON originates from the medial division of the dorsal ramus of the C2 spinal nerve, the LON arises from the ventral rami of the C2 and C3 spinal nerves, and the TON comes from the dorsal ramus of the C3 spinal nerve (3).

These nerves are susceptible to compression, entrapment, or irritation as they traverse between interfacial planes due to the loss of cervical lordosis, or musculoskeletal dysfunction in the upper cervical segments (4). Spondylosis of the lateral atlantoaxial joints can also result in irritating the convergent C2 dorsal root ganglion (DRG) and may be overlooked as a primary cause of refractory occipital neuralgia (5).

Minimally invasive treatments, such as nerve blocks, pulsed radiofrequency ablation (RFA) of the C2 DRG, and other rhizotomy procedures performed on the C2 nerve root, are commonly employed for diagnosing and managing occipital neuralgia (5-13). The classic approach to target the C2 DRG involves imaging guidance using fluoroscopy or computed tomography (5,7,8,12,14); the radiographic image-guided pulsed RFA of the C2 DRG has been described as having high response rates (15,16). However, the challenge with the radiographic approach arises from the difficulty in visualizing the C2 DRG, leading to complications, extended procedure time, and radiation exposure (5,7). This lack of clarity can increase the risk of inadvertently puncturing the vertebral artery and/or spinal dura mater, resulting in accidental intraarterial or intrathecal injections, spinal fluid leakage, or even spinal cord punctures (7).

Here, we introduce a novel ultrasonographic approach for quick and accurate C2 DRG identification and needle placement guidance. This ultrasonographic method was developed based on the distinctive anatomy of the C2 DRG.

Method

Unlike the C3-C8 foramina, which are ventral to the corresponding facet joints, the C2 foramen is positioned more posteriorly, dorsal to the C1-C2 atlantoaxial joint and longitudinally aligns with the cervical facet joints of C2-C3 and C3-C4 (Fig. 1A). This distinctive anatomical feature allows for rapid identification of the C2 foramen in the ultrasonographic longitudinal-axis view (Figs. 1B, 2A), followed by rotating the probe to further expose the C2 DRG in the oblique-axis view (Figs. 1C, 2B).

Ultrasound-guided Access of the C2 DRG

Pulsed RFA of the C2 DRG

Pulsed RFA of the C2 DRG was performed in patients who had exhibited a favorable response to an ultrasound-guided C2 DRG block with local anesthetic. During pulsed RFA, once the C2 DRG has been accessed with ultrasound guidance, sensory (50 Hz) and motor (2 Hz) electrical stimulations were conducted using the model RFG-4 RFA lesion generator (Cosman Medical). A sensory stimulus of $\leq$ 1.0 V confirmed the targeted innervated distribution (either the greater occipital nerve innervated area or the lesser occipital nerve innervated area), and a motor stimulus of $\leq$ 3.0 V confirmed the absence of a motor response. Subsequently, pulsed RFA was performed at sequential temperatures of 42°C, 45°C, 50°C, and 55°C, each for 90 seconds.

Patient Selection

Institutional review board approval was obtained for this observational study from the Department of Pain of Beijing Xuanwu Hospital, Capital Medical University, Ethics Examining Committee of Human Research. From January 2022 through February 2023, 38 patients with chronic occipital neuralgia diagnosed according to the diagnostic criteria outlined in the International Headache Society Classification of Headache Disorders Third Edition (17), underwent a C2 DRG pulsed RFA procedure using our new ultrasound-guided approach to identify the C2 DRG. The cohort's demographic data are presented in Supplementary Table 1.

Contraindications to C2 DRG pulsed RFA include coagulopathy, infection, an intracranial tumor, pregnancy, and an allergy to local/general anesthetics. Written informed consent was obtained from all patients.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics 22.0 (IBM Corporation). Data are presented as mean ± SEM. To evaluate the repeated measurements of NRS-11 pain scores, one-way repeated measures

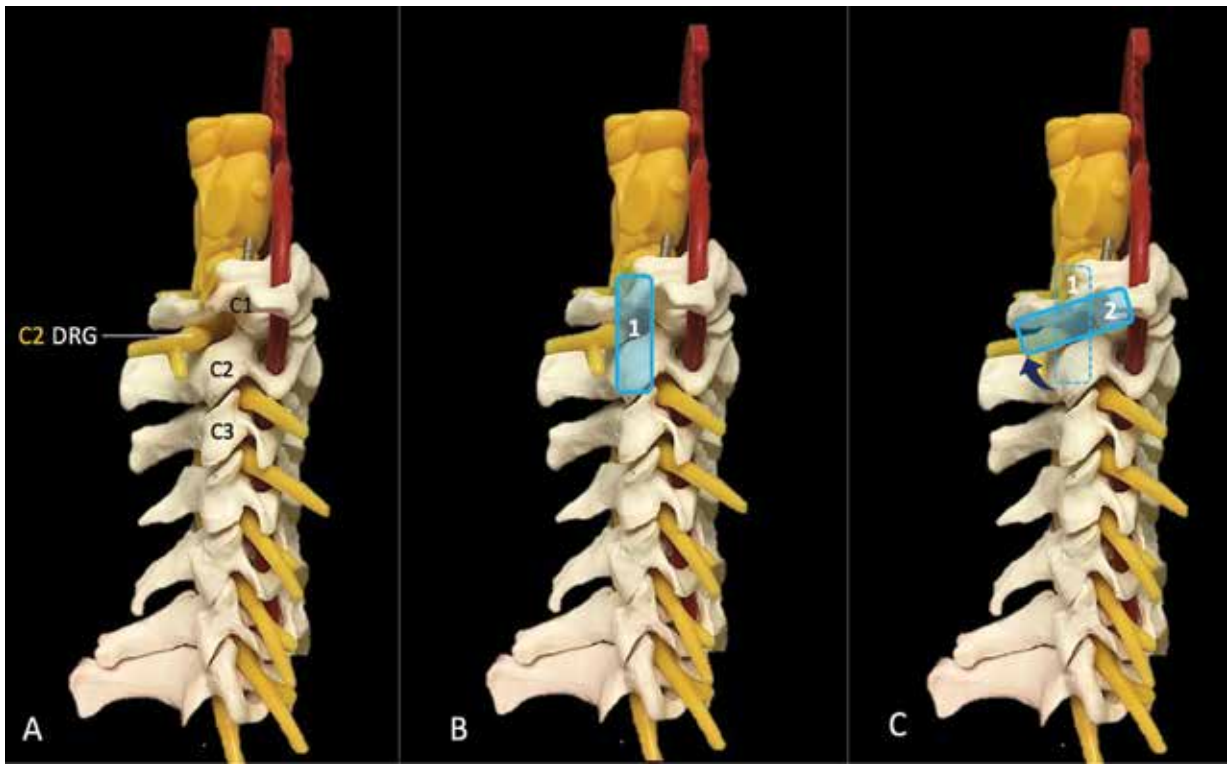

Fig. 1. *Anatomy of the C2 dorsal root ganglion (DRG).*
A. Lateral view of the cervical spine, with the C2 DRG marked.
B. The longitudinal axis probe position to visualize the C2 foramen between the C1 and C2 Lamina.
C. The oblique axis probe position to expose the C2 DRG.

analysis of variance (ANOVA) was employed. Statistical significance was defined as $P < 0.05$.

Identifying the C2 foramen with a longitudinal-axis view: the "Stage-light Sign"

We positioned each patient laterally with a pillow for head and neck support. The low-frequency curvilinear ultrasound probe was placed in-plane with the longitudinal axis of the patient just caudal to the mastoid process for the initial longitudinal-axis view (Fig. 2A). A view of the continuous high-echogenic bony contour representing the C2 and C3 lamina and facet joints was obtained with slight ventral or dorsal adjustments of the probe.

The C2 foramen is cephalad to this continuous bony contour, and its identification is further facilitated by visualizing the deeper tissues between the C1 and C2 lamina (Fig. 3). This is because ultrasonographic waves can penetrate the posteriorly oriented C2 foramen, resulting in echo signals reflected from the spinal cord and the lamina of the contralateral side (Fig. 3). In this view, the C2 DRG appears as a hypoechoic oval structure within the C2 foramen, deep to the obliquus capitis inferior muscle (Fig. 3). We referred to this characteristic longitudinal view as the "Stage-light Sign", with the "light bulb" representing the C2 DRG and the "Stage-light" highlighting the deeper tissue. This feature serves as an easily identifiable sonographic feature for rapidly locating the C2 foramen. It is important to adjust the depth setting to at least 6-8 cm to best visualize the deeper tissue as the "Stage-light Sign," even though the C2 foramen and the C2 DRG are much shallower (Fig. 3).

Exposure of the C2 DRG With an Oblique-axis View: the "Turtle Sign"

Although the C2 DRG can be well visualized as the "Stage-light Sign" in the longitudinal-axis view, the adjacent lamina obstructs the in-plane needle access to the C2 DRG in this view (Fig. 3). To solve this problem, the caudal end of the probe is rotated dorsally once the "Stage-light Sign" has been obtained

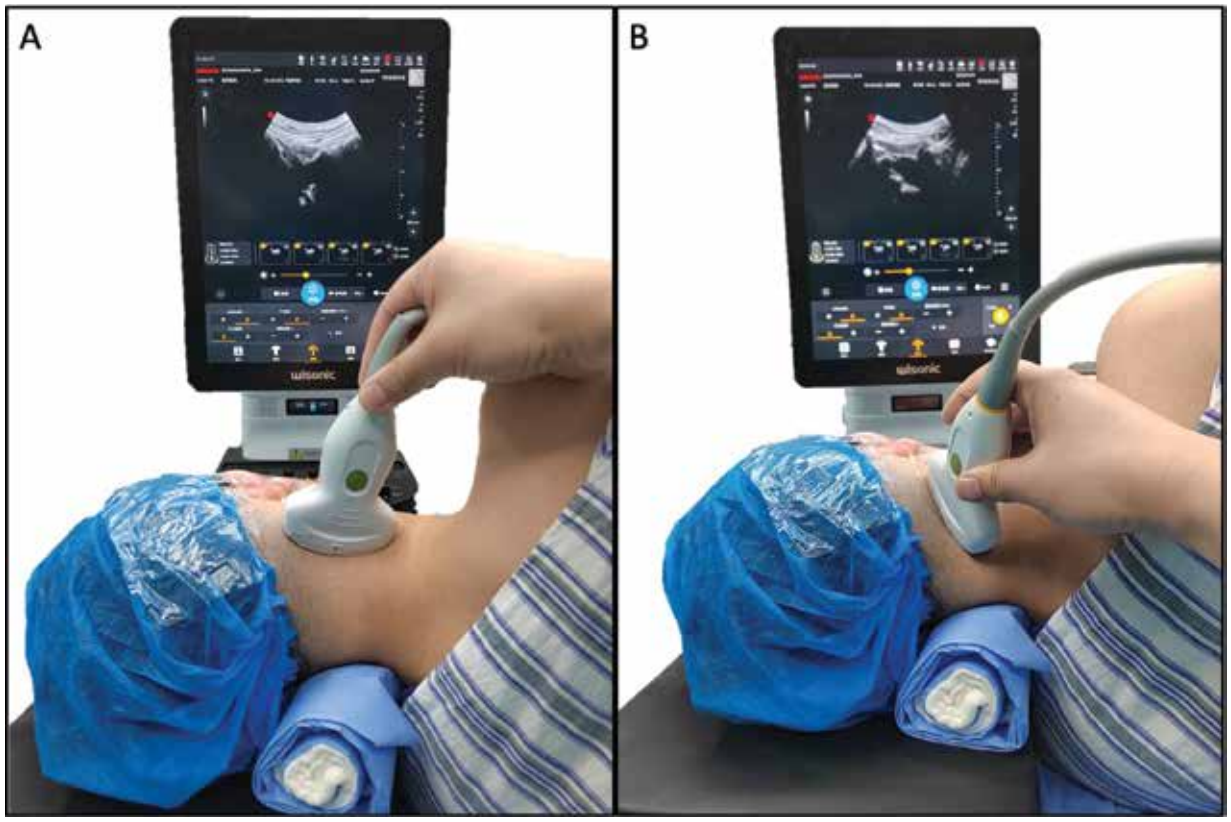

Fig. 2. *Probe placement.*
A. Probe placement for the longitudinal-axis view of the C2 foramen.
B. Probe placement for the oblique-axis view to expose the C2 DRG.

(Figs. 1C, 2B), keeping the C2 DRG in view until both the C2 DRG and spinal cord are visible together (Fig. 4). In this view, the C2 DRG appears as a round/oval hypoechoic structure underneath the obliquus capitis inferior muscle at the C2 foramen, while the deeper spinal canal appears as a large oval low-echo structure enveloping the spinal cord, which is seen as a smaller oval low-echo structure within the spinal canal (Fig. 4A-2A). We call this image the "Turtle Sign," with the C2 DRG as the turtle head, while the spinal canal and spinal cord resemble the turtle shell. The C2 DRG, representing the "turtle head," is positioned posterior to the C1 transverse process, providing separation from the anteriorly located vertebral artery (Fig. 4B-2B).

Following the exposure of the C2 DRG with the oblique-axis "Turtle Sign" and localization of blood vessels with color Doppler, a needle can be inserted from dorsal-caudal to ventral-cephalad using the in-plane technique under dynamic live ultrasound guidance to reach the C2 DRG (Fig. 4A-3A). Notably, the vertebral artery is visible and protected by the C1 transverse process (Fig. 4B-3B).

Confirmation of the Correct Needle Tip Position

The correct placement of the needle tip with our ultrasonic approach was initially confirmed with fluoroscopy. In the first several cases of ultrasound-guided needle insertion, fluoroscopic images were captured (Fig. 5), closely resembling those obtained with the fluoroscopy-guided method and showing the distribution of the injected contrast medium along the C2 spinal nerve (Fig. 5B). The correct needle tip position was also validated using electrical sensory stimulation, eliciting paresthesia in the headache area in all patients; the voltage needed was 0.35 ± 0.02 V. In addition, the correct needle tip position was further supported by treatment outcomes, as pulsed RFA treatment resulted in sustained pain reduction (Fig. 6).

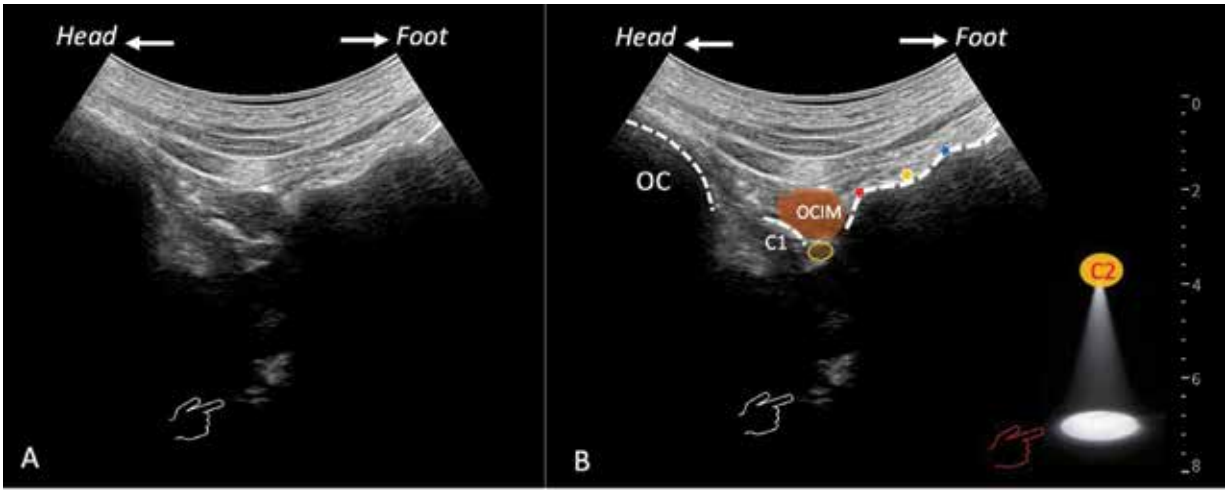

Fig. 3. *Sonographic longitudinal axis view of the C2 foramen: the "Stage-light Sign."*
A. Original sonographic image.
B. Sonographic image with graphical indication. The C2 dorsal root ganglion is marked as an open yellow oval, and the obliquus capitis inferior muscle is marked as a filled orange oval. C1 indicates the C1 Lamina, and OC represents the occiput. The red star indicates the C2/C3 facet joint, the blue star indicates the C3/C4 facet joint, and the yellow dot marks the place where the medial branch nerve is located. The white fingers point to the sonographic echo signal through the C2 foramen, and the red finger points to the "Stage-light Sign."

Results

Performance of Ultrasound-guided C2 DRG Access

The following procedural parameters were prospectively obtained: the time required to identify the C2 DRG target, the time needed to reach the target from the point of skin puncture, the number of puncture attempts required to reach the target, and the minimum sensory testing voltage to evoke paresthesia responses in the cutaneous occipital nerve distributions. The following clinical outcomes were obtained: serial pain severity assessed by the Numeric Rating Scale (NRS-11) at baseline and up to 3 months post the C2 DRG pulsed RFA procedure. The NRS-11 ranges from 0 to 10, where 0 indicates no pain and 10 indicates the highest pain level.

Accessing the target C2 DRG with this new ultrasound-guided approach was substantially faster than the conventional fluoroscopy-guided approach. Using the ultrasound-guided approach, it took 36.2 ± 2.2 seconds to finalize the view of the C2 DRG, with a single puncture attempt and 36.3 ± 2.5 seconds needed to reach the target with the needle. In contrast, in 15 patients who underwent the classic fluoroscopy-guided approach to access the C2 DRG in our practice, required 329.9 ± 33.6 seconds to find the target, with 5 ± 0.5 puncture attempts and 983.0 ± 116.6 seconds needed to reach the target with the needle. No major adverse events, such as weakness, total spinal anesthesia, local anesthetic intoxication, hemorrhage, or infection, were observed after pulsed RFA of the C2 DRG.

Discussion

We are introducing a novel ultrasonographic method for quick and precise access of the C2 DRG. The C2 foramen can be easily identified by the "Stage-light-Sign" in the longitudinal-axis view, while the "Turtle-Sign" in the oblique-axis view further exposes the C2 DRG beneath the obliquus capitis inferior muscle. The ability to visualize the spinal cord and the vertebral artery during needle insertion under dynamic imaging results in improved safety advantages.

Our ultrasonographic technique represents an improvement over previously published methods, in which the ultrasound probe was placed longitudinally (11,18), in a position similar as our initial "Stage-light-Sign" (Fig. 2A). However, accessing the C2 DRG in this view is challenging due to its being blocked by the adjacent C1 and C2 lamina, as demonstrated in Fig. 3. To address this problem, we introduced a second step: rotating the probe to obtain the "Turtle-Sign" in the oblique-axis view. This rotation further exposes the C2 DRG, making needle access much easier.

Although other ultrasound-guided techniques

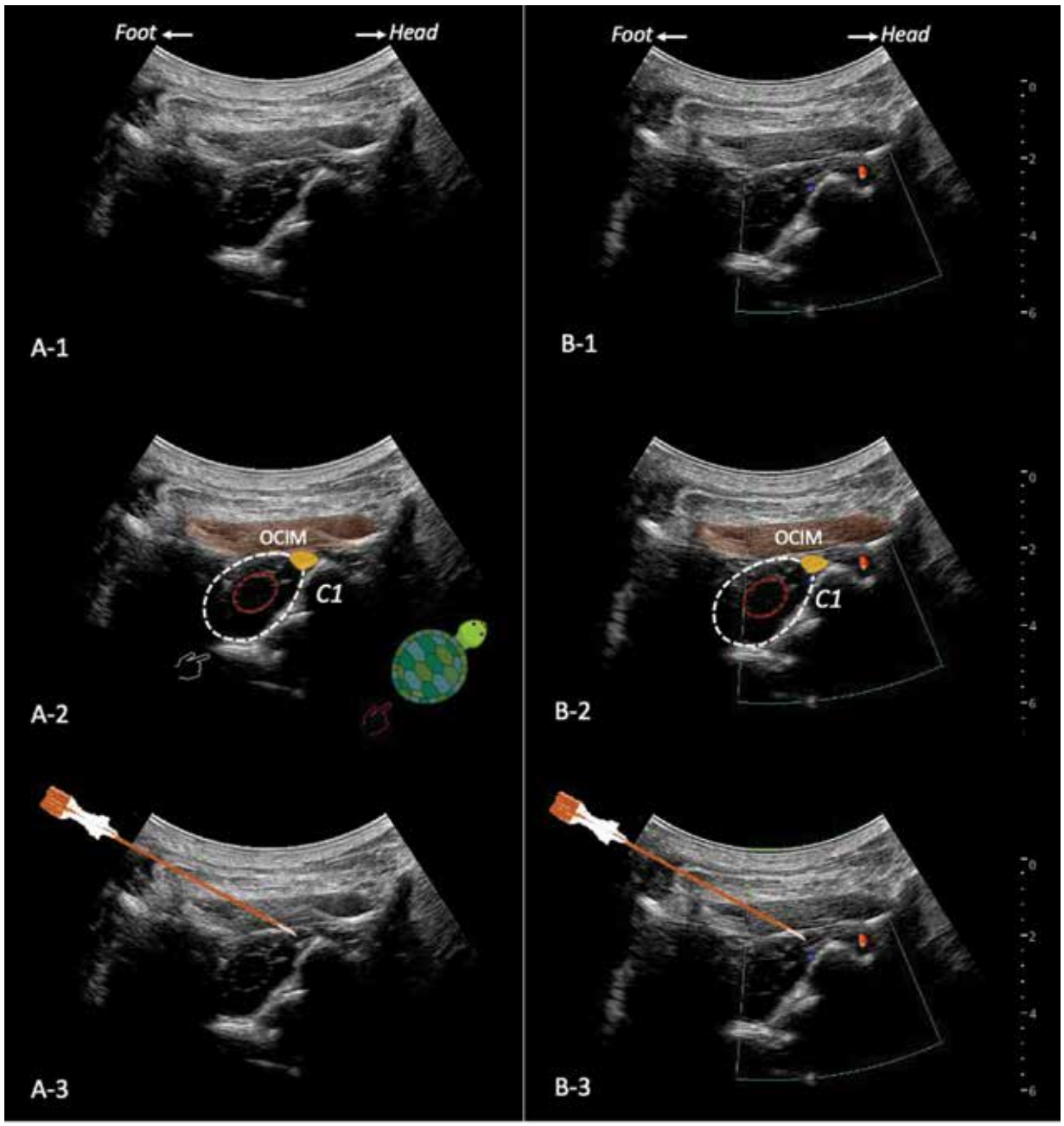

Fig. 4. *Sonographic oblique axis view to expose the C2 dorsal root ganglion (DRG): the "Turtle Sign."*
A-1. Original sonographic image.
B-1. Original sonographic image with color Doppler showing the vertebral artery.
A-2. Sonographic imaging with graphical indication. The C2 DRG is marked as a yellow oval, and the obliquus capitis inferior muscle is marked as a long orange shape. The white dotted oval indicates the spinal canal, and the red dotted oval indicates the spinal cord. The white finger points to the sonographic echo of the spinal canal bone, and the red finger points to the turtle cartoon. The C2 DRG resembles a turtle head, while the spinal canal, along with the spinal cord, resembles a turtle shell.
B2. Color Doppler sonographic image with graphical indication.
A-3. Sonographic image with needle tip.
B-3. Color Doppler sonographic image with needle tip.

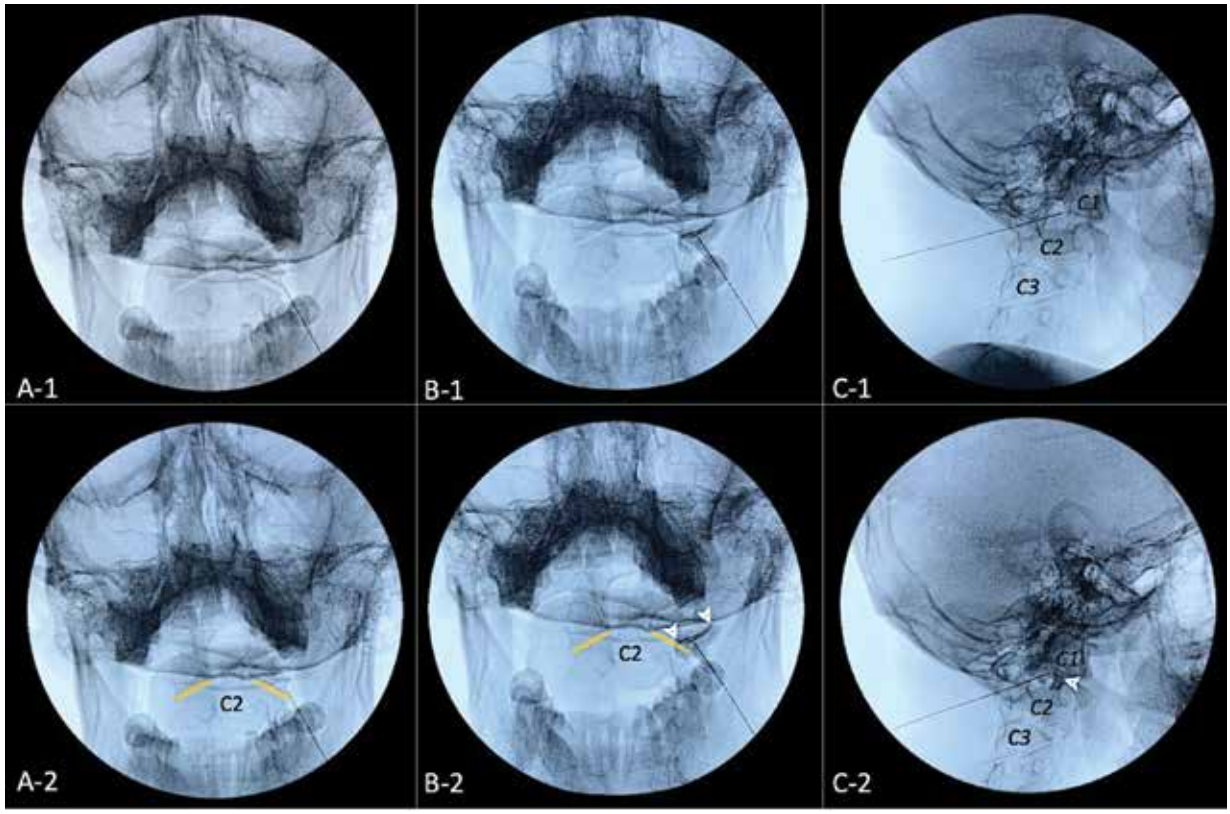

Fig. 5. *Confirmation of needle tip position with fluoroscopy.*
A-1. The anteroposterior fluoroscopic view showing that the needle tip touches the lateral edge of the atlanto-axial joint (AAJ).
A-2. A-1 image with the AAJ marked in orange.
B-1. The anteroposterior fluoroscopic view displays the spread of 0.5 mL of contrast medium along the C2 spinal nerve.
B-2. B-1 image with the AAJ marked in orange and contrast medium spread marked by 2 white arrowheads.
C-1. The lateral fluoroscopic view showing that the needle tip is aligned with the medial margin of the C2 foramen.
C-2. The lateral fluoroscopic view showing the spread of 0.5 mL of contrast medium along the C2 spinal nerve, which is marked by the white arrowhead.

for accessing the C2 DRG have been reported, these methods are suboptimal. For example, Hua, et al (6) positioned their probes obliquely from the C2 spinous process to the C1 transverse process, using the same probe location as in an ultrasound-guided GON block (19). Li, et al (10,20) placed their probe in the short axis view between C1 and C2, with the target site set as the medial aspect of the atlantoaxial joint.

Ultrasound-guided GON block has been widely employed in clinical practice. In this approach, the ultrasound probe is positioned between the C2 spinous process and the C1 transverse process, with the GON localized superficially to the obliquus capitis inferior muscle (19). Although this is an excellent technique for a GON block, it is not ideal for pulsed RFA treatment, as the GON can diverge into multiple branches at this location (19). On the other hand, since the C2 nerve contains all the nerve fibers of the GON and some fibers of the LON (3), pulsed RFA treatment of the C2 DRG has been successfully employed in managing chronic headache caused by GON and LON neuralgia (6,8-11,20). Our study confirms the safety and efficacy of ultrasound-guided pulsed RFA treatments of the C2 DRG. Since our study primarily focuses on the correct position of the needle tip, we only followed the patients for up to 3 months after the procedure.

It is important to note that while pulsed RFA was employed in this study, our ultrasonographic method is equally applicable to procedures involving diagnostic or therapeutic injections or placing peripheral nerve stimulation electrodes to the C2 DRG. In fact, all patients who underwent pulsed RFA in this study had successful

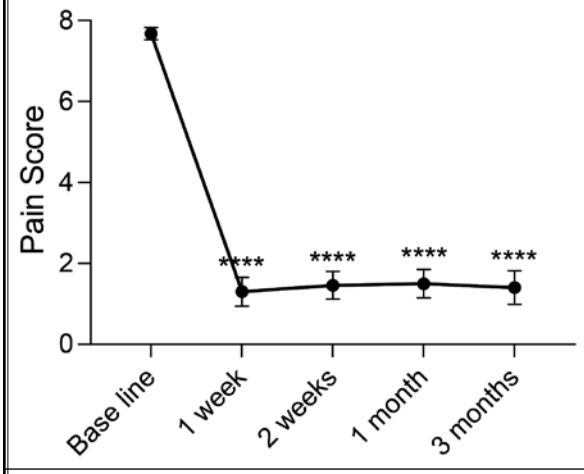

Fig. 6. *Sustained pain reduction after pulsed radiofrequency ablation of the C2 dorsal root ganglion (DRG) with the ultrasound-guided method*.
Pulsed radiofrequency of the C2 DRG with the ultrasound-guided method resulted in a substantial reduction in postprocedure pain, lasting for at least 3 months. Data are presented as mean ± SEM and analyzed using one-way analysis of variance (ANOVA), with "****" indicating $P < 0.0001$.

ultrasound-guided diagnostic blocks of the C2 DRG. Of note, the target for the ultrasound-guided GON block is superficial to the obliquus capitis inferior muscle. In contrast, the target for our ultrasound-guided C2 DRG treatment is located underneath the obliquus capitis inferior muscle and is more lateral than the target for an ultrasound-guided GON block (Fig. 7). Moreover, in addition to the GON, targeting the C2 DRG can manage pain from the LON as well (Fig. 7).

Limitation

We only followed patients for up to 3 months. Further study is needed to determine if ultrasound-guided pulsed RFA of the C2 DRG provides longer pain relief.

Conclusion

We have developed a novel ultrasonographic method to quickly and accurately access the C2 DRG, with the initial "Stage-light-Sign" to identify the C2 foramen and the subsequent "Turtle-Sign" to expose

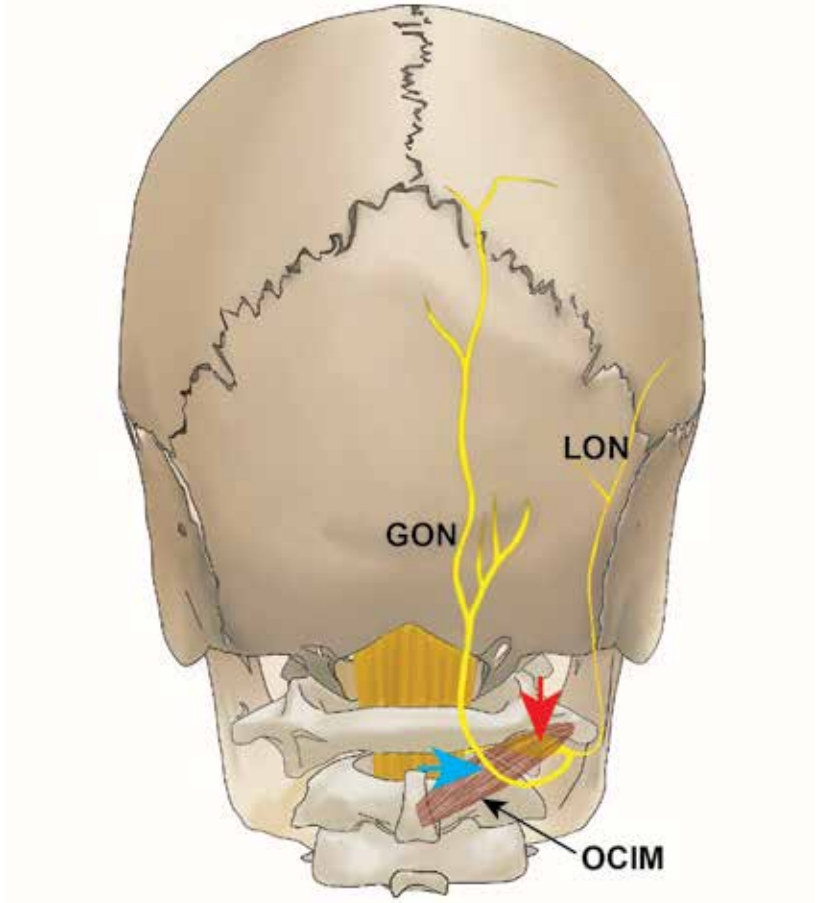

Fig. 7. *The relationship between the C2 dorsal root ganglion (DRG), the obliquus capitis inferior muscle, and the occipital nerves*.
The C2 DRG (red arrow) is located beneath the obliquus capitis inferior muscle (black arrow) and posterior to the C1 transverse process. The C2 spinal nerve branches into the greater occipital nerve medially and the lesser occipital nerve laterally. The greater occipital nerve wraps around the obliquus capitis inferior muscle, lying superficially on it, where it is targeted by an ultrasound-guided greater occipital nerve block (cyan arrow).

the C2 DRG. This method is likely to facilitate treating occipital neuralgia by targeting the C2 DRG.

Acknowledgment

The authors thank Na Zhao, BSN for her assistance.

Author Contribution

L.H. developed the method, managed the patients, conducted the analysis, and wrote the manuscript; W.Z. developed the method and managed the patients; P.P.S edited the manuscript; X.L., J.Z., and H.W. contributed to patient management; L.Y. organized the study; Z.G. designed the study, supervised the analysis, and wrote the manuscript.

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Supplementary Table 1. ***Characteristics of patients undergoing pulsed radiofrequency ablation of the C2 dorsal root ganglion via an ultrasonographic approach. Values are mean (SD) or number (percentage).***

	n = 38
Gender; women	28 (73.6%)
Age; y	49.2 (13.6)
Headache duration; y	10.7 (10.1)
Headache laterality	
Left	17 (44.7%)
Right	15 (39.5%)
Bilateral	6 (15.8%)
Headache area	
GON[1]	14 (36.8%)
LON[2]	10 (26.3%)
'G+L' ON[3]	14 (36.8%)

[1]Greater occipital nerve distribution; [2]lesser occipital nerve distribution; [3]greater and lesser occipital nerve distribution.