Retrospective Analysis

Fluoroscopic Analysis of Cannula Tip Location During Radiofrequency Thermocoagulation of the Trigeminal Ganglion

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Disclaimer: There was no external funding in the preparation of this manuscript.

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 manuscript.

Manuscript received: 10-25-2022
Revised manuscript received: 12-14-2022
Accepted for publication: 01-04-2023

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Background: Trigeminal neuralgia (TN) is the most common excruciating cranial neuralgia in the elderly population. Radiofrequency thermocoagulation (RFT) of the trigeminal ganglion is an alternative treatment for medically intractable patients with TN. RFT cannula tip position is an important issue since it is related to treatment outcome and patient safety.

Objectives: The purpose of this study was to evaluate the fluoroscopic position of a cannula tip when a maximal stimulation-induced paresthesia was obtained and the treatment outcome using a Barrow Neurological Institute (BNI) pain scale.

Study Design: Retrospective analysis.

Setting: An interventional pain management practice in South Korea.

Methods: The final cannula tip position obtained under maximal electrical stimulation of the face was analyzed using previously saved fluoroscopic images.

Results: The cannula tip was located exactly in the clival line in 10 patients (29.4%) with maxillary division (V2) TN. There were 24 patients of V2 TN (70.5%) in whom the cannula tip was located below the clival line. Over 50% of cannula tips were located at –11 mm to –15 mm below the clival line in mandibular division (V3) TN. Forty-four patients (83%) who received RFT in the trigeminal ganglion demonstrated BNI I or II.

Limitations: The number of patients with V3 TN was smaller than that of V2 TN. Only short-term efficacy was evaluated, but not long-term efficacy or recurrence rate of facial pain.

Conclusions: Nearly 70% of patients in V2 TN and all patients in V3 TN, the cannula tip was positioned below the clival line. RFT of the trigeminal ganglion showed a successful treatment outcome with BNI I or II in 83% of patients.

Key words: Cannula tip, clival line, fluoroscopic position, pain scale, stimulation-induced paresthesia, radiofrequency

Pain Physician 2023: 26:283-288

Trigeminal neuralgia (TN) is the most common excruciating cranial neuralgia in the elderly population. Women are more frequently affected than men at a ratio of 1:2.14. In South Korea, the incidence of TN was reported as 100.21/100,000. The characteristic clinical features of TN include an electric shock-like, recurrent, and stabbing pain in the trigeminal nerve division (1,2).

The severe and excruciating nature of pain intensity associated with TN can impair the physical and psychosocial well-being of the patient. Therefore, it is crucial initiating active treatment to overcome those adversities. Fortunately, up to 90% of patients can achieve pain reduction using medical therapy alone. However, 10% to 15% of TN cases demonstrate a minimal response to medication with various side effects (3,4). Radiofrequency thermocoagulation (RFT) of the trigeminal ganglion is an alternative treatment option

for patients who are poor candidates for microvascular decompression or show serious side effects to medication. An advantage of RFT is the selective ablation of the trigeminal branch, which is essential for single division TN. Recent studies (5-8) revealed that RFT of the trigeminal ganglion resulted in Barrow Neurological Institute (BNI) pain scale I or II in 71.7% of patients, with a median time to recurrence of 36 months.

Correct and accurate positioning of the RF cannula is critical for successful RFT and to minimize unwanted and serious complications. The wrong cannula trajectories during rhizotomy of the trigeminal ganglion can result in serious complications, including carotid artery injury, intracerebral hemorrhage, cranial nerve injury, or brain stem injury, and even blindness (9-12).

The cannula tip is usually guided by a lateral cranial fluoroscopic view toward the targeted trigeminal ganglion. However, the final placement of the cannula is determined by an adequate response to an electrical stimulation in an awake patient. Despite the seemingly adequate location of a cannula connected to a thermal electrode in fluoroscopic images, the cannula should be advanced or withdrawn slightly until obtaining the maximal stimulation-induced paresthesia.

For RFT of the maxillary division (V2) of the trigeminal ganglion, a cannula is usually advanced until the clival line is in lateral cranial fluoroscopic view (7,13,14). However, when administering electrical stimulation in that cannula position, only limited patients could feel stimulation-induced paresthesia in a painful face. For patients who could not feel stimulation-induced paresthesia, slight withdrawal or advancement of an electrode could generate proper stimulation-induced paresthesia. Therefore, the cannula tip position obtained after a maximal electrical stimulation response is an ultimate target for RF lesioning.

The primary endpoint of this study was to analyze the fluoroscopic position of the cannula tip when a maximal stimulation-induced paresthesia was obtained. The secondary endpoint was to identify the BNI pain intensity score after RFT of the trigeminal ganglion in TN patients.

Methods

Patients

This retrospective study was approved by our institutional review board (2022-08-023), which waived the need for an informed patient consent. Patients who were diagnosed with idiopathic or classic TN and who received RFT of the trigeminal ganglion under C-arm guidance due to intractable facial pain were included (August 2019 to September 2022). TN patients with a single V2 or mandibular division (V3) were included. Before RFT, carbamazepine (400 mg/d) and an infraorbital or mental nerve block by ultrasound guidance according to affected trigeminal branch were administered to patients. TN was diagnosed according to the beta version of the Third Edition of the International Classification of Headache Disorders (15). A magnetic resonance imaging (MRI) was performed in all patients to confirm any vascular lesion or tumor around the trigeminal ganglion. Patients with secondary TN, TN affecting both V2 and V3, and TN affecting the ophthalmic division (V1) were excluded.

We used Clinical Data Warehouse Version 2.5 (CDW, Planit Healthcare, Seoul, Korea) to identify patients who received RFT of the trigeminal ganglion under the diagnosis of TN using the key words "trigeminal neuralgia and radiofrequency."

RFT Procedure

The patient was laid in an operation bed in the supine position with a 30° to 40° head extension. Subsequent to proper patient positioning, the foramen ovale (FO) was searched with a 10° to 15° lateral rotation from the midline toward the ipsilateral side and at a 30° to 35° caudal tilt. At this fluoroscopic view, the FO could be easily found between the mandibular ramus laterally and the maxilla medially. If the mandibular ramus or maxilla superimposed the FO, the C-arm was rotated ipsilateral to the right or left side to place the FO at the midpoint between the mandibular ramus and the maxilla. When the FO was visualized clearly, local skin infiltration with 1% lidocaine was done 2-3 cm lateral to the angle of the lips.

During the RFT procedure, light sedation was given using intravenous midazolam at 0.02 mg/kg and sufentanil 5 mcg. We maintained a light sedation to allow the patient's cooperation during electrical stimulation. If patients complained of severe pain during RFT of the trigeminal ganglion, additional midazolam, and sufentanil were injected. Electrocardiography, pulse oximetry, and blood pressure were measured during the entire RFT procedure and until 30 minutes after the completion of RFT. Oxygen (3 L/min) was supplied using a facial mask.

A 10-cm 22-G curved RF cannula with a 5-mm active tip was used. Subsequent to clear identification of

the FO, the cannula was advanced into the center of the FO using a pinpoint view. Before the final puncture of the FO, nicardipine 1 mg or sufentanil 5 mcg was injected to minimize the sudden increase of heart rate and blood pressure.

After successfully entering the FO, the cannula was advanced until the clival line in case of the V2 TN. In case V3, the cannula was advanced 2-3 mm further just after entering the FO, but it was not advanced until the clival line.

Once the cannula was determined to be in a suitable position in the lateral fluoroscopic view, an electrical stimulation from an RF generator (Baylis Medical, Montreal, QC, Canada) ranging between 0.1 V to 0.3 V at a 50 Hz frequency was applied. Then, we checked whether the electrical stimulation was felt in the original region of the facial pain. If an inadequate or weak electrical stimulation was felt on the face, the cannula was advanced or withdrawn slightly under C-arm guidance according to the stimulation effect. Facial paresthesia experienced under > 0.4 V was defined as an inadequate or weak electrical stimulation. If successful electrical stimulation felt within 0.1 V to 0.3 V was obtained in the V2 or V3 area, final thermal heating was performed once at 75 °C for 60 seconds. A fluoroscopic image in lateral cranial view showing successful electrical stimulation within 0.1 V to 0.3 V was saved and transferred to the Picture Archiving and Communication System (PACS; M6, INFINITT Healthcare, Seoul, Korea).

Analysis of Fluoroscopic Position of the Cannula Tip

The analyses of the final position of the cannula tip obtained under the maximal electrical stimulation of the face were performed using the previously saved images in PACS. These analyses were performed by one of the authors (JH Hong) who had previous experiences in RFT of the trigeminal ganglion for > 5 years.

First, the clival line was identified in all saved fluoroscopic lateral cranial images. Second, the cannula tip position was determined based on the clival line, which is beyond, within, or below the clival line (Fig. 1). To evaluate the distance between the cannula tip and the clival line, a length-measurement instrument installed in INFINITT PACS M6 was used. If the cannula tip was located exactly within the clival line, it was presented as 0 mm (Fig. 1B). If the cannula tip was located 5 mm beyond or below the clival line, it was indicated as +5 mm or –5 mm from the clival line, respectively (Fig. 1A and 1C).

Outcome of Trigeminal Ganglion Radiofrequency Thermal Ablation

Patients were evaluated using the BNI pain scale (Table 1) to determine the effect of RFT of the trigeminal ganglion. This evaluation was performed one month after the procedure. One of the authors (JH Park) who was not involved in the RFT of the trigeminal ganglion evaluated the outcome according to the BNI pain scale, as well as other complications.

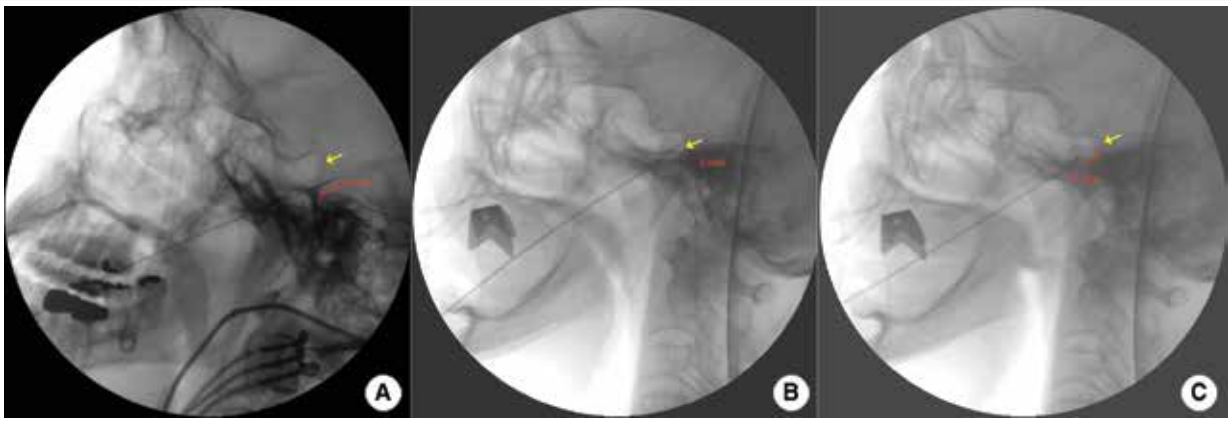

Fig. 1. *Cannula tip position beyond the clival line (A), in the clival line (B), and below the clival line (C). Clival line indicated by a yellow arrow. A cannula tip, measured 5 mm beyond or below the clival line, is indicated as +5 mm (A) or −5 mm (C) from the clival line, respectively. If the cannula tip was located exactly within the clival line, it is indicated as 0 mm (B).*

Statistics

Values are presented as number of patients (%) or mean (standard deviation) (Table 2).

Results

The medical records and fluoroscopic view of 60 patients were analyzed fully. Among them, 5 patients were excluded due to TN involving both V2 and V3. Two patients with TN involving V1 were also excluded. Therefore, 53 patients with a single V2 TN or V3 TN were analyzed finally (Table 2).

The mean age of TN was 65.5 (10.5) years. Among them, most were women and right-side facial pain was predominant. Patients with V2 were more frequent than V3 (34 [64.2] vs 19 [35.8], Table 2).

There were no patients in V2 TN and V3 TN showing the position of the cannula tip beyond the clival line. The cannula tip was located exactly in the clival line in 10 patients (29.4%) with V2 TN. Twenty-four patients with V2 TN (70.5%) showed a cannula tip located below the clival line. The mean distance between the cannula tip and the clival line was –4.8 mm in case of V2 TN. All cannula tips in cases of V3 TN were located below the clival line. Among them, > 50% of cannula tips were located between –11 mm and –15 mm in cases of V3 TN. The mean distance between the cannula tip and the clival line was –15 mm in cases of V3 TN (Table 3).

The outcome of RFT of the trigeminal ganglion in patients of V2 TN and V3 TN was evaluated according to the BNI pain scales. Patients who received RFT of the trigeminal ganglion demonstrated BNI I or II in 44 patients (83%, Table 4).

Various degrees of post-RFT facial hypoesthesia were observed in almost all patients. However, sensory changes were not certain in 5 patients (9.4%). Intrabuccal hematoma, diminished corneal reflex, masseter muscle weakness, and atrophy of temporal muscle weakness were not observed.

Table 1. *BNI pain scale.*

BNI Pain Scale	Definition
I	No trigeminal pain, no medication required
II	Occasional pain not requiring medication
III	Some pain adequately controlled with medication
IV	Some pain not adequately controlled with medication
V	Severe pain, no pain relief

Abbreviation: BNI, Barrow Neurological Institute.

Table 2. *Demographic data and affected trigeminal branch.*

Age (y)	65.5 (10.5)
Gender (M/W)	24/29
Body Mass Index (kg/m^2) Pain Duration (mo) Side (right/left)	23.5 (7.2) 35.9 (12.5) 35/18
Trigeminal Branch	
V2	34 (64.2)
V3	19 (35.8)
Total	53 (100)

Values are mean (SD) or number of patients (%).
Abbreviations: y, years; M, men; W, women; mo, month(s); V2, maxillary division; V3, mandibular division; SD, standard deviation.

Table 3. *Fluoroscopic position of the cannula tip from the clival line and distribution of patients with V2 and V3 TN.*

	V2 n (%)	V3 n (%)
Beyond the clival line		
0 mm – +5 mm	0 (0)	0 (0)
Clival line		
0 mm	10 (29.4)	0 (0)
Below the clival line		
−1 mm – −5 mm	13 (38.2)	0 (0)
−6 mm – −10 mm	10 (29.4)	3 (15.7)
−11 mm – −15 mm	1 (2.9)	11 (57.8)
−16 mm – − 25 mm	0 (0)	5 (26.3)
Total	34 (100)	19 (100)

Abbreviations: V2, maxillary division; V3, mandibular division; TN, trigeminal neuralgia.
Values are number of patients (%).

Table 4. *Outcome of trigeminal ganglion RF thermal ablation in patients of V2 and V3 TN.*

BNI Pain Intensity Score	Number of Patients (%)
I	37 (69.8)
II	7 (13.2)
III	8 (15.0)
IV	1 (1.9)
V	0 (0)
Total	53 (100)

Abbreviations: RF, radiofrequency; V2, maxillary division; V3, mandibular division; TN, trigeminal neuralgia; BNI, Barrow Neurological Institute; I, no trigeminal pain, no medication required; II, occasional pain not requiring medication; III, some pain adequately controlled with medication; IV, some pain not adequately controlled with medication; V, severe pain, no pain relief.

Discussion

This study demonstrated that the cannula tip located within or below the clival line in case of V2 TN produced a maximal electrical stimulation of the face. However, the cannula tip was located below the clival line in more than half of patients (70.5%) with V2 TN (Table 3). How far away a cannula tip should be located from the clival line is a critical issue since vital structures, such as brain stem, cavernous sinus, and basilar artery, are close and its position is related to the treatment result (8). A previous anatomical study (16) showed extended trigeminal compressive balloons reached 10.96 mm ± 5.54 mm beyond the clival line. In that position, the average distance from the balloon to the brain stem and the basilar artery was 6.89 mm and 12.12 mm, respectively (16). However, when a cannula was located far beyond the clival line, it resulted in dense right hemiparesis, which was confirmed to be a brain stem injury by MRI (12).

In this study, no patients had a cannula tip position beyond the clival line for RFT of the V2 TN or V3 TN. However, according to a previous retrospective study (17), 69% of patients undergoing RFT cases showed the position of the cannula tip beyond the clival line. Specifically, the cannula tip was located 1.57 mm to 3.05 mm beyond the clival line. Only 7% of patients who have undergone RFT demonstrated the cannula tip just in the clival line (17).

In this study, finally analyzed fluoroscopic images were obtained after electrical stimulation by the RF generator. During the RFT procedure, subjective paresthesia description under conscious sedation is a critical step, which determines neurophysiological localization of the trigeminal ganglion. Subjective paresthesia description, which was felt above 0.4 V by an electrode, was considered inadequate or weak and the position of the cannula was changed. According to our previous experiences, most successful RFTs of the trigeminal ganglion were achieved when an electrical stimulation within the range of 0.1V to 0.3 V at a 50 Hz frequency was applied and subsequent facial paresthesia was provoked. Since an electrical stimulation was applied into a trigeminal cistern, a stimulation under lower voltage could provoke facial paresthesia compared to the voltage of RFT of the spinal medial branch (7,8).

The trigeminal sensory system, located within the Meckel's cave, is divided into 2 portions, the trigeminal ganglion and the triangular plexus. For safe and successful RFT of the trigeminal ganglion, the triangular plexus appears to be the best place to generate more selective lesions. The triangular plexus comprises from the posterior margin of the trigeminal ganglion to the path over the upper petrous ridge (17). It is the retrogasserian portion of the trigeminal nerve and corresponds to the dorsal sensory root (18). If the triangular plexus is a final target of RF cannula placement, the cannula should be placed beyond the clival line since the triangular plexus is always present posterior to the trigeminal ganglion. When the cannula is placed in the clival line, not beyond the clival line, only 53% of RFT could reach the triangular plexus (19). If the cannula should be placed beyond the clival line, it should not go beyond 10 mm from the clival line (20).

In RFT of the V2 TN, nearly 70% of patients could feel stimulation-evoked paresthesia for the cannula tip placed below the clival line, even with a mean distance of –4.8 mm from the clival line to the cannula tip. Therefore, if a stimulation-evoked paresthesia is inadequate or weak with the cannula position in the clival line, the cannula needs to be withdrawn slightly rather than advanced. For V3, the cannula tip position is always below to that of V2 (8,17). More than half of patients with V3 TN had a cannula tip position between 11 mm to 15 mm below to the clival line (Table 3). In such cases, the position of the cannula should be checked by lateral cranial fluoroscopic view as soon as the FO was punctured. According to our previous experiences, only 2-3 mm further advancement of the cannula just after the puncture of the FO could reach the ideal target for RFT of the V3.

Although microvascular decompression (MVD) is considered to be the first choice of treatment in patients with classic TN, some patients cannot tolerate it. Moreover, patients who did not show any vascular compression or contact with the trigeminal nerve are not ideal candidates for MVD (4). In clinical practice, RFT is an alternative option for patients who cannot tolerate MVD (8,21). Moreover, RFT is less invasive compared to the surgical treatment of MVD. A recent study (22) showed that pulsed RF of the trigeminal nerve in patients of TN revealed significant reduction of pain. According to a recent meta-analysis (21), the mean initial pain relief achieved by RFT was 95.31%; whereas, the range of pain relief was 77.8% to 100%. Accordingly, our study also had excellent therapeutic results of RFT of the trigeminal ganglion, as 83% of patients showed initial pain relief (BNI I or II) (Table 4). Various degrees of post-RFT facial hypoesthesia were observed in almost all cases, except 5 patients. Facial hypoesthesia, subsequent to RFT of the trigeminal ganglion, indi-

cates a successful sensory system impairment, which is essential for a good therapeutic result (21). Therefore, there is a debate whether facial hypoesthesia or numbness should be considered as a complication of RFT or not (8,21).

Limitations

This study includes several limitations. First, the number of patients with V3 TN was smaller than that of V2 TN. Second, only short-term efficacy was evaluated without evaluating long- term efficacy or recurrence rates of facial pain after RFT of the trigeminal ganglion. Lastly, we evaluated the cannula tip position based on the clival line in the fluoroscopic images. However, the clival line is hard to identify in the beginning of treatment by pain physicians of RFT of the trigeminal ganglion. Other practical fluoroscopic landmarks, which are easy to be identified, need to be suggested.

Conclusions

Nearly 70% of patients in V2 TN and all patients in V3 TN demonstrated the cannula tip position below the clival line. RFT of the trigeminal ganglion showed a successful treatment outcome with the BNI I or II pain scale in 83% of patients.

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