Prospective Study

Comparison of Efficacy and Safety of CT-Guided Radiofrequency Thermocoagulation Through Foramen Rotundum Versus Foramen Ovale for V2 Primary Trigeminal Neuralgia

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Background: Primary trigeminal neuralgia (TN) is one of the most severe facial pain syndromes. TN affects patients' quality of life and, when severe, can lead to depression and increase social burden.

Objectives: This retrospective study aimed to compare efficacy and safety of computed tomographic (CT)-guided percutaneous radiofrequency thermocoagulation (RFT) through the foramen rotundum (FR) versus through the foramen ovale (FO) for treatment of maxillary division (V2) TN.

Study Design: A prospective study.

Setting: Shengjing Hospital of China Medical University.

Methods: Seventy patients with V2 TN were randomly assigned to 2 groups: RFT-FR group (n = 35) and RFT-FO group (n = 35). Visual Analog Scale (VAS), the Medical Outcomes Study 36-Item Short-Form Health Survey, the total efficacy, complications, and recurrence rate were assessed before and after surgery at different time points.

Results: Compared with the preoperative VAS, the postoperative VAS in the RFT-FR and RFT-FO groups both decreased significantly ($P < 0.05$). There was no significant difference in VAS between the 2 groups ($P > 0.05$); in both groups quality of life improved to varying degrees after RFT. In the RFT-FO group, the physical component summary (PCS) and mental component summary (MCS) were significantly lower than in the RFT-FR group at 1 week, 2 weeks and 1 month ($P < 0.05$). After 3 months, the PCS and MCS of the RFT-FO group gradually increased, so the 2 groups no longer differed significantly ($P > 0.05$). The total incidence of complications in the RFT-FR and RFT-FO groups was 20.0% (7/35) and 62.9% (22/35), respectively, and differed significantly ($P < 0.05$).

Limitations: This study cohort size is small, but we will gradually increase the number of patients later. Second, there may be acquiescence bias or response bias. Third, the punctures under the more commonly used C-arm imaging guidance deserve to be evaluated in the future.

Conclusions: CT-guided RFT through the FR and FO are both an effective, minimally invasive treatments for V2 TN that can relieve pain effectively.

Key words: Radiofrequency thermocoagulation, primary trigeminal neuralgia, foramen rotundum, foramen ovale, neuropathic pain

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Primary trigeminal neuralgia (TN), one of the most severe facial pain syndromes (1), is characterized by recurrent episodes of paroxysmal facial pain, several times a day, of abrupt onset and intermittent episodes (2,3). TN affects patients' quality of life (4,5) and, when severe, can lead to depression and increase

social burden. Presently, the pathogenesis of TN is unknown. It is necessary to find safe and effective treatment methods with few side effects.

TN can be treated with drugs and surgery. The most commonly used drug treatments are anticonvulsants and antidepressants, but they are not effective. Moreover, long-term drugs have serious side effects that are often not tolerated. Surgical treatments include craniotomy (e.g., microvascular decompression, trigeminal tractotomy, etc) and percutaneous minimally invasive surgery (e.g., radiofrequency thermocoagulation [RFT], percutaneous retrogasserian glycerol rhizotomy, percutaneous balloon compression, etc) (6). Since Sweet (7) used the Gasserian ganglion RFT to treat TN, RFT is currently recognized as one of the relatively safe, effective, and repeatable minimally invasive surgical methods. It has been widely used in the treatment of TN (8). The temperature range of RFT is generally 75-90 °C. As the temperature of RFT increases, the complication of numbness and other nerve injury gradually increases. In our previous study, we found that at a lower temperature (68 °C) RFT could provide good analgesia and lower complications (9), but it could not completely avoid the risk of other asymptomatic branch injuries. Among the 3 divisions of the trigeminal nerve, involvement of the maxillary division (V2) is most frequent (10). In the Gasserian ganglion, the 3 nerve fiber divisions of the trigeminal nerve are in close contact and partially interconnected. Therefore, by puncture of the Gasserian ganglion through the foramen ovale (FO), the V2 division is difficult to accurately locate. This approach can easily involve the ophthalmic division (V1) or the mandibular division (V3), resulting in complications. For TN with simple V2 division involvement, puncturing the maxillary nerve RFT through the foramen rotundum (FR) may be a better approach method. A study shown that the FR approach was associated with significantly shorter operation time than the FO approach (11). Therefore, only patients with V2 TN were selected for this study. Under the guidance of computer tomography (CT), low-temperature RFT was applied through the FR or the FO, and the clinical efficacy and safety were observed and compared.

There have been many studies of Gasserian ganglion RFT treatment for TN, but few studies performed RFT through the FR. In this study, we selected patients with V2 primary TN alone and excluded those with secondary TN involving or associated with V1 and V3. The efficacy, complications, and recurrence rate of V2 TN treated by lower temperature RFT through either the FR or FO were compared.

Methods

Patients

Seventy patients diagnosed with V2 TN, from January 2015 to December 2016, were selected by the Department of Pain Management, Shengjing Hospital of China Medical University (Fig. 1). Patients were randomly assigned to 2 groups according to the order of enrollment: RFT through the FR (RFT-FR group, n = 35) and RFT through the FO (RFT-FO group, n = 35). All patients were informed of the risks and complications before surgery.

Patients met the criteria for the diagnosis of primary TN in the International Classification of Headache Disorders, Third Edition (beta version) (ICHD-3), published by the International Headache Society in 2013 (12), and these inclusion criteria: (1) age > 30 years; (2) only the V2 division distribution area was involved; (3) moderate to severe pain, Visual Analog Scale (VAS) > 5 score 24 hours before enrollment; (4) duration of TN > 3 months; and (5) pain was not controlled after standardized drug treatment, oral antiepileptic and other analgesic drugs, and/or experienced intolerable adverse effects.

Exclusion criteria: (1) secondary TN, such as intracranial space occupying lesions based on conventional magnetic resonance imaging of head and trigeminal nerve; (2) TN involving V1 or V3 divisions; (3) puncture regional infection; (4) mental illness, mental disorders, or disturbance of consciousness such that patient could not cooperate; (5) severe liver, kidney, heart, or lung disease; (6) abnormal preoperative coagulation function; (7) local anesthetic drug allergy; and (8) had prior surgery for TN.

Surgical Procedure

Under CT guidance, the patient was placed in a supine position and a RF electrode plate was attached to the ipsilateral shoulder. Vital signs were monitored during the operation. Intravenous access was established and ceftriaxone sodium (Shanghai Roche Pharmaceuticals Co. Ltd., China) was administered, to prevent infection, 30 minutes before surgery. Both groups used 21 Ga RF needles (Active Tip, 5 mm). RFT-FR group underwent RFT through the FR from 50°C to 68°C for 180 seconds. RFT-FO group underwent RFT through the FO from 50°C to 68°C for 180 seconds.

RFT-FR group: using the lower margin of the zygomatic arch approach, the intersection of the ipsilateral zygomatic arch and the anterior branch of the

mandible was located as the entry point. Local anesthesia was administered with 0.5% lidocaine, and the FR was used as the target for puncture. RFT-FO group: using the Hartel Gasserian ganglion anterior approach, 2.5 to 3 cm lateral to the affected side of the mouth was located as the entry point. Local anesthesia was administered with 0.5% lidocaine along the established puncture angle and path; the FO was used as the target for puncture. Location of needle tip was confirmed by CT scan, and the direction of the needle adjusted until the needle tip was located at the FR or the FO. The RFT instrument (Baylis Medical Inc., Montreal, Canada) was connected and tested: (1) 50 Hz, 0.1 to 0.3 V tested sensation, induced pain sensation in V2 distribution area; and (2) 2 Hz, 0.1 V tested motor function. The position of the needle tip was adjusted until the sensation completely covered the V2 distribution area, avoiding involvement of V1 (eyelash hypoesthesia) and V3 (jaw muscle movement) divisions. After the position was confirmed, local anesthesia with 1.5%-2% lidocaine (0.2 mL) was infused, and temperature was increased gradually from 50°C to 68°C. The patient's reactions were observed during the operation. Postoperatively, patients remained at bedrest for 24 hours and were observed for 2-3 days. All the procedures were performed by a pain physician with extensive clinical experience.

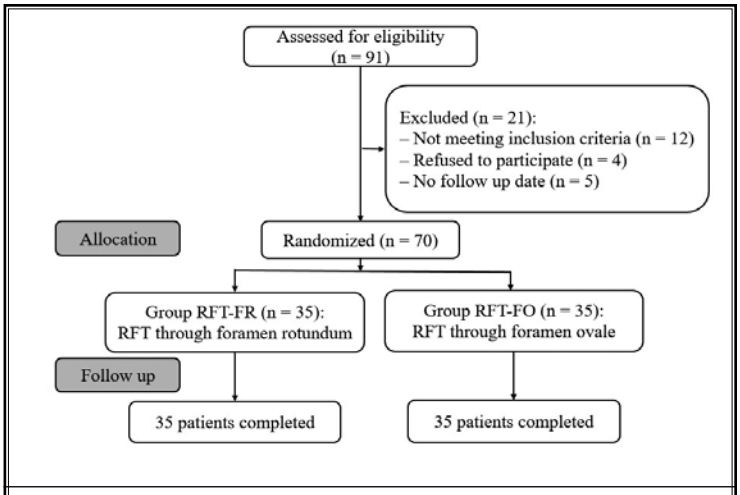

Fig. 1. *Study flowchart. Of 91 initial patients, 70 patients were randomly assigned and underwent RFT.*

Observations and Follow-up

Preoperative data, including gender, age, pain duration, pain location, preoperative VAS, and dosage of antiepileptic drugs were recorded. Follow-up assessments were performed at 1 week, 2 weeks, 1 month, 3 months, 6 months, and 1 year after surgery, respectively. Patients were evaluated single blind at follow-up visits by nonsurgical medical staff.

(1) Pain score: Assessed by VAS. 0 points (painless) to 10 points (the most intolerable pain).
(2) The Medical Outcomes Study 36-Item Short-Form Health Survey evaluation (13): The patients' quality of life before and after surgery was assessed at each time point, including physical and mental status. Physical states included physical function, physical role function, bodily pain, and general health; mental state included vitality, social function, emotional role function, and mental health. Physical component summary (PCS) and mental component summary (MCS) were summarized and calculated. PCS and MCS were calculated according to each domain score and the data of the Chinese adults model (14).
(3) The total efficacy rate: According to subjective symptoms and clinical signs, it was categorized into 3 levels: excellent, effective, and ineffective. Excellent: pain, numbness and hyperalgesia disappeared, and resumed the premorbid level of labor; Effective: pain and numbness reduced, and level of labor improved; Ineffective: no improvement of symptoms. The total efficacy rate (%) = [(excellent + effective)/n] × 100%.
(4) Complications and side effects: short-term facial hematoma, nausea, vomiting, and headache; long-term facial numbness, decreased corneal reflex, and masticatory muscle weakness.
(5) Recurrence rate.

Statistical Analysis

Statistical analysis was performed using SPSS software version 22.0. Data were assessed for normality using the Kolmogorov-Smirnov test. Variables with a normal distribution were compared using one-way analysis of variance and the values were expressed as mean ± standard deviation. The Kruskal-Wallis test was used for comparisons of variables that did not meet criteria of normal distribution. Values were expressed as median (interquartile range). Categorical data were analyzed using chi-square or Fisher's exact test. P values < 0.05 were considered statistically significant.

Results

Patients Characteristics

The preoperative patient characteristics of groups RFT-FR and RFT-FO were compared. There were no significant differences in the gender, age, pain duration, pain location, preoperative VAS, and the dosage of antiepileptic drugs (i.e., carbamazepine, gabapentin and pregabalin) ($P > 0.05$) (Table 1).

Intraoperative Conditions

The operation was successfully completed in all patients. The plain CT scan confirmed that the needle tip was located at the FR; 3-dimensional reconstruction was performed to further confirm the needle position. The needle path was located at the FR (Fig. 2[A] and [B]); the plain CT scan confirmed that the needle tip was located in the FO; and 3-dimensional reconstruction was performed to further confirm the needle position. The needle path was located in the FO (Fig. 2[C] and [D]).

Table 1. *Preoperative patient characteristics of RFT-FR and RFT-FO groups.*

Parameters	Group	
	RFT-FR	RFT-FO
Patients (n)	35	35
Gender (F/M, %)	20 (57.1%)/15 (42.9%)	21 (60.0%)/14 (40.0%)
Age (y, range)	57.56 ± 6.43 (33–-73)	57.79 ± 6.29 (34–-76)
Preoperative Pain Duration (mo, range)	11.38 ± 5.61 (3–-21)	11.24 ± 5.37 (3–-22)
Pain Location (n, %)		
Right	21 (60.0%)	22 (62.9%)
Left	14 (40.0%)	13 (37.1%)
Preoperative VAS	6.78 ± 1.43	6.69 ± 1.57
Preoperative Drug Dosage		
Carbamazepine (mg/d, n)	533.54 ± 80.33 (16)	534.02 ± 79.75 (14)
Gabapentin (g/d, n)	2.31 ± 0.54 (9)	2.29 ± 0.48 (10)
Pregabalin (mg/d, n)	454.63 ± 74.58 (10)	455.27 ± 75.25 (11)

Data are presented as numbers (%) of patients or mean ± SD.
Abbreviations: RFT-FR, = radiofrequency thermocoagulation through foramen rotundum; RFT-FO, = radiofrequency thermocoagulation through foramen ovale,; VAS, = visual analog scale.

VAS Score

Compared with preoperative VAS, the postoperative VAS in RFT-FR and RFT-FO groups both decreased significantly ($P < 0.05$). This difference was maintained up to one year. After 6 months, a slight increase in VAS was observed in both groups; there was no significant difference between the 2 groups ($P > 0.05$) (Fig. 3).

SF-36 Evaluation

Both groups of patients had improved quality of life of varying degrees after RFT. After the surgery, the PCS and MCS of both groups increased at each observation time point. Compared with preoperative scores, the differences were significant ($P < 0.05$). In the RFT-FR group, PCS and MCS began to increase at one week, and the improvement of quality of life was maintained for a longer period of time; while in the RFT-FO group, the PCS and MCS were significantly lower than the RFT-FR group at 1week, 2 weeks and 1 month ($P < 0.05$). After 3 months, the PCS and MCS of the RFT-FO group gradually increased, so they were no longer significantly lower than the RFT-FR group ($P > 0.05$) (Fig. 4).

Total Efficacy Rate

One year after surgery, the total efficacy rate of RFT-FR and RFT-FO groups was 80.0% and 74.3%, respectively. RFT-FR group had a higher total efficacy rate than RFT-FO group, but the difference was not statistically significant ($P > 0.05$) (Table 2).

Complications and Side Effects

In both groups, the operation was completed within 30 minutes. Postoperatively, patients in both groups had facial hematoma, headache, nausea, vomiting, and hyperalgesia in the involved area. After partial cold compress, symptomatic treatment and absolute supine, the complications recovered quickly, without any subsequent serious adverse reactions.

In the RFT-FO group, V1 trigeminal nerve injury occurred, manifested as forehead numbness, eyelash hypoesthesia, decreased corneal reflex, but no visual deterioration. All patients with decreased corneal reflex returned to normal within one month. In additions, also V3 trigeminal nerve injury occurred, manifested as varying degrees of masticatory muscle weakness and numbness in the innervation region of the mandible. The total incidence of complications in the RFT-FO group was 62.9% (22/35).

In the RFT-FR group, there were no V1 or V3 trigeminal nerve injuries. There was no forehead numb-

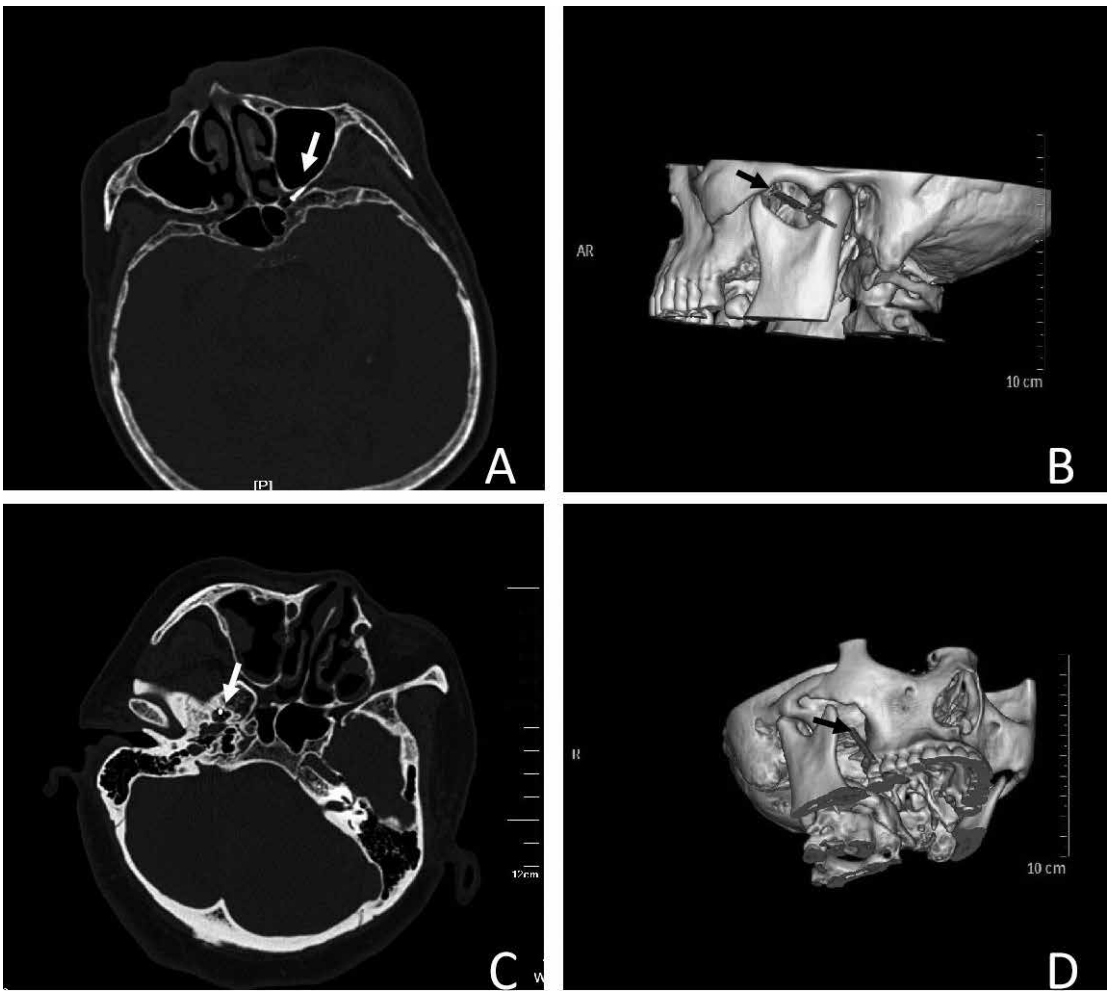

Fig. 2. *(A) Plain CT scan shows the needle tip was located at the left side of the FR, as indicated by the arrow. (B) The 3-dimensional reconstruction shows the needle and the direction, located at the left side of the FR, as indicated by the arrow. (C) Plain CT scan shows the needle tip was located in the right side of the FO, as indicated by the arrow. (D) The 3-dimensional reconstruction shows the needle and the direction, located in the right side of the FO, as indicated by the arrow.*

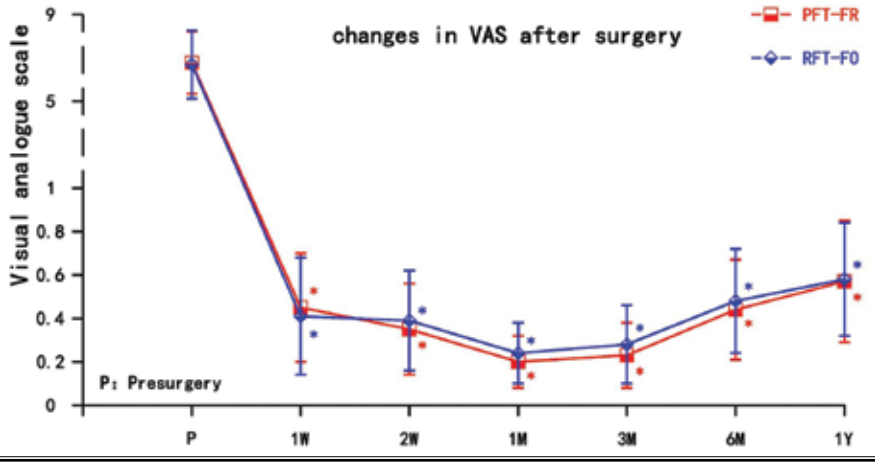

Fig. 3. *Comparison of VAS in RFT-FR and RFT-FO groups. Data are presented as mean ± SD.*
* compared to preoperative, $P < 0.05$; compared with RFT-FO, $P > 0.05$.

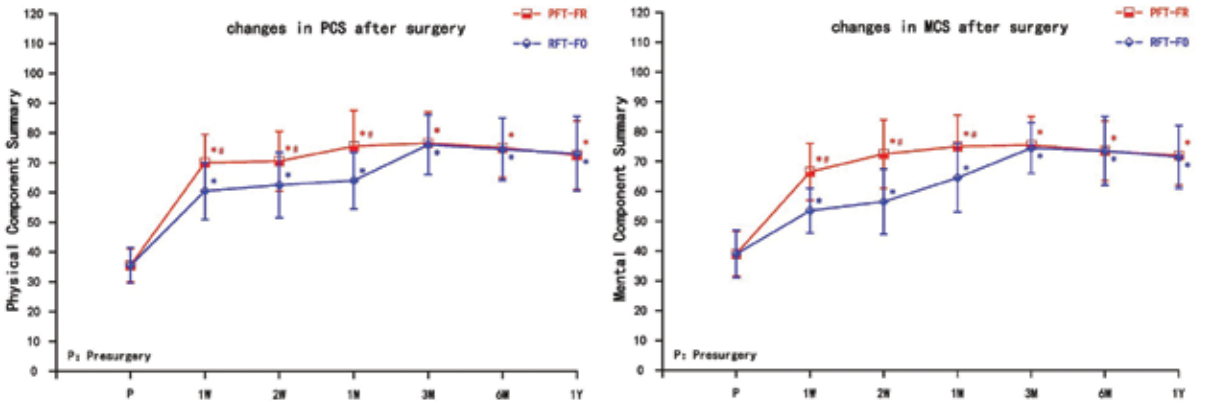

Fig. 4. *Comparison of PCS and MCS in RFT-FR and RFT-FO groups. Data are presented as mean ± SD.*
Abbreviations: PCS, Physical Component Summary; MCS, Mental Component Summary. * compared to preoperative, $P < 0.05$. #compared with RFT-FO, $P < 0.05$.

Table 2. *The total efficacy in RFT-FR and RFT-FO groups.*

Group	n	Excellent	Effective	Ineffective	The Total Efficacy (%)
RFT-FR	35	17	11	7	80.0
RFT-FO	35	14	12	9	74.3*

Abbreviations: RFT-FR, = radiofrequency thermocoagulation through foramen rotundum;, RFT-FO, = radiofrequency thermocoagulation through foramen ovale.
* compared with RFT-FO, $P > 0.05$.

ness, no eyelash hypoesthesia and no decreased corneal reflex, no masticatory muscle weakness, and no puncture into the nasal cavity or other inherent puncture complications. The total incidence of complications in the RFT-FR group was 20.0% (7/35).

After the operation, all patients experienced varying degrees of numbness in the V2 distribution area, which gradually recovered or decreased within one year. No permanent facial paralysis occurred after surgery, and no other serious or permanent complications occurred. In terms of complications and side effects, the incidence of the RFT-FO group was higher than that of the RFT-FR group. The difference was statistically significant ($P < 0.05$) (Table 3).

Recurrence Rate

The recurrence rates one year after surgery of RFT-FR and RFT-FO groups were 22.9% (8/35) and 20.0% (7/35), respectively; the difference was not significant ($P > 0.05$).

Discussion

The efficacy of RFT is confirmed, and it has the advantages of limited trauma, target testing selection, and repeated treatment. It is a routine method for treating TN (15). The incidence of TN is the highest in the V2 division. The puncture path commonly used in RF is a percutaneous puncture of the Gasserian ganglion through the FO (16), but this approach is prone to V1 and V3 injury.

In this study, VAS scores did not differ significantly between the RFT-FR and RFT-FO groups at any observation time point ($P > 0.05$). Therefore, both surgical procedures can effectively relieve the clinical symptoms and have significant therapeutic efficacy (17,18). CT-guided selective RFT via the FR (17) appears to be a feasible, safe, and effective treatment for isolated V2 idiopathic TN. Compared with the FO group (18), the procedural time of the FR group was shorter (29.2 ± 9.3 vs 45.4 ± 22.13 minutes, $P < 0.05$), V1 and V3 divisions had less nonspecific blocks, and fewer adverse outcomes including masticatory weakness (0/15 vs 5/12) and corneal perforation (0/12 vs 1/15) . Postoperative complications occurred in both groups, but were significantly more frequent in the RFT-FO group ($P < 0.05$). Compared with RFT through the FO, treatment with RFT through the FR significantly improved the quality of life in the early period, which may be related to fewer, less postoperative complications. Three months after surgery early complications had resolved, includ-

ing, absorption of hematomas, the disappearance of low intracranial pressure headache after bed rest, and recovery of injured nerves of V1 and V3 divisions, so the quality of life no longer differed between the 2 groups. The currently reported puncture approach for the RFT treatment of the V2 division is primarily the Hartel anterior approach. Due to the large variation in the location of the FO in the skull base (19), the rate of puncture failure using the Hartel anterior approach is higher (20), which is accompanied by nerve and vascular injury beyond the V2 division. There are many reports of V1 and V3 division injuries caused by RFT through the FO (21,22). The RFT-FO group of this study also experienced injury of V1 and V3 divisions; whereas, in the RFT-FR group, after puncturing the target, the V2 division allodynia was induced by sensory stimulation without V1 and V3 division paresthesia. During the course of RFT, no abnormalities were observed in the V1 and the V3 division functions, indicating that the RFT through the FR had minimal effect on V1 and V3 divisions. No masticatory muscle weakness and decreased corneal reflex were found in RFT-FR group.

RFT temperature is associated with nerve injury. The higher the RFT temperature, the greater is the possibility of adjacent nerve injury and the greater is the severity of complications. A comparison of different temperatures of RFT in the treatment of TN found that complications, such as numbness, in the high temperature group (> 80 °C) were more and lasted longer than in the low temperature group (< 75 °C) (23). However, lowering RFT temperature can lead to poor pain relief and higher postoperative recurrence rate. Therefore, RFT temperature can affect the recurrence rate (24,25). A study that compared 3 RFT low temperature groups (62 °C, 65 °C, and 68 °C), 62 °C and 65 °C did reduce complications, but the recurrence rate increased significantly (26). In an earlier investigation, we found that 68 °C RFT could achieve higher patient satisfaction with less complications than 75 °C (9). So we chose 68 °C reducing recurrence rate while avoiding complications. The innermost part of the FO is the V1 division, the central part is the V2 division, and the outer part is the V3 division. When the puncture needle passes through the FO to reach the maxillary nerve, it can easily cause injury to the mandibular nerve. Therefore, the position of the FO restricts the range of the RFT temperature. Pulsed radiofrequency (PRF) analgesic effect is not achieved solely through temperature, but through neuromodulation (27). Studies have confirmed that PRF can effectively treat TN (28). In the later period, we will further study the treatment of PRF in TN. When the RFT puncture needle enters the Meckel's cavity, it is easy to stimulate the meninges-induced dizziness, nausea, and vomiting, and can cause the loss of cerebrospinal fluid (29); consequently, headaches caused by low intracranial pressure appear, and the required bed rest time increases. In the positioning test, RF current stimulation of the mandibular nerve can cause muscle contraction, resulting in severe pain. V2 trigeminal nerve fibers are closely adjacent to the V1 and V3 nerve fibers in the Gasserian ganglion. RFT treatment can easily cause V1 injury (30), causing keratitis, corneal hypoesthesia, diminished corneal reflex, and even blindness in severe cases. The incidence rate of V1 division injury was from 5.7% to 15% (16,31,32). Injury of the V3 division can cause decreased masticatory muscle strength and even masseter muscle weakness. The incidence rate of V3 division injury was from 7% to 10.5% (16,22,23). When the RF needle was punctured into the skull through the FO, it was sometimes necessary to repeatedly adjust the position of the needle until the electrical stimulation induced V2 area paresthesia (32,33). During actual surgery, repeated adjustments of the puncture needle position may still fail to stimulate (V2) division paresthesia, leading to treatment failure. Repeated puncture can lead to intracranial tissue damage and intracranial hematoma formation (34). Only the maxillary nerve is located at the external orifice of the FR, and it is not adjacent to V1 and V3 divisions; therefore, at this location, there is no risk of injury to other nerves. Moreover, higher RFT temperatures could be selected

Table 3. *Complications and side effects in RFT-FR and RFT-FO groups*.

Complications	Group	
	RFT-FR	RFT-FO
Facial hematoma, n (%)	1 (2.9)	3 (8.6)
Headache, n (%)	1 (2.9)	2 (5.7)
Nausea and vomiting, n (%)	1 (2.9)	4 (11.4)
Eyelash hypoesthesia, n (%)	0 (0.0)	2 (5.7)
Decreased corneal reflex, n (%)	0 (0.0)	2 (5.7)
Forehead numbness, n (%)	0 (0.0)	2 (5.7)
Hyperalgesia in V2 distribution area, n (%)	4 (11.4)	5 (14.3)
Masticatory muscle weakness, n (%)	0 (0.0)	2 (5.7)
Incidence of complications (%)	7 (20.0)*	22 (62.9)

Abbreviations; RFT-FR, = radiofrequency thermocoagulation through foramen rotundum; RFT-FO, = radiofrequency thermocoagulation through foramen ovale. * compared with RFT-FO, $P < 0.05$.

to reduce postoperative recurrence rate and prolong time to recurrence. The entrance through the FR does not enter the Meckel's cavity, and no loss of cerebrospinal fluid occurs, reducing the chance of low intracranial pressure headache, meningitis, and intracranial infection. The V2 division passes out of the skull through the external orifice of the FR. The position of the nerve trunk is fixed and no branch is issued. There is no anatomical variation. The bony landmarks are exact, and RFT of the V2 division can be completely performed without entering the FR. The depth of the puncture needle through the FR is short, and there is no need to repeatedly adjust the orientation and depth, so the risk of puncture injury is low.

RFT is a neuroselective disruptive technology. The high frequency current generated by the RF instrument causes ions in the tissue to oscillate, which, in turn, heats the tissue causing local temperature rise. The target tissue heating coagulates conductive pain neurofibrils (Aδ and C-type), whereas conductive tactile neurofibrils (Aα and Aβ-type) can tolerate relatively high temperatures and will not be destroyed. Therefore, gradually heating can selectively destroy the sensory nerves, while preserving the tactile fibers relatively. Pain relief can be achieved, but the sense of touch can partially or completely be preserved (35). By cutting off the sensory pathway, the action potential is hindered and pain is relieved (29,36). However, other studies have found that when RF is applied to peripheral nerves, light and electron microscopy observations show complete loss of unmyelinated fibers and almost complete loss of myelin fibers in all lesions (37). RFT temperature also plays a very important role in the severity of complications and side effects. In animal experiments, RFT with different temperatures and durations were used on rabbits' Gasserian ganglion. Under light microscopy, neuronal degeneration and necrosis, nuclear atrophy, and unclear fragmentation of nucleoli can be observed. Degeneration of myelin sheath, segmental degeneration, axon sparseness, continuity interruption, and uneven distribution of nerve fibers were also observed. Adjacent tissues appeared edematous, peripheral blood vessels were dilated and congested, inflammatory cells infiltrated, and tissue necrosis was observed. Immunohistochemical examination showed that neurofilament protein, acetylcholinesterase, and muscarinic receptors expression increased gradually with the prolongation of postoperative time. RFT at 70°C may be an optimal temperature that causes the greatest damage to the trigeminal ganglion, which significantly reduces nerve activity (38). Under the electron microscope, after RFT at 80°C, the structure of the nerve axons disappeared instantly and showed vacuolar degeneration; after 30 days, axonal disintegration and necrosis were observed and no regeneration was observed; collagen fibers hyperplasia was seen at 60 days, and the axon had still not regenerated. That is, the nerve conduction function disappeared immediately after thermocoagulation and did not recover after 60 days (39). The size and shape of RF lesions were also important for reducing complications and side effects in patients. At different temperatures and time, the size of the lesion increased (40). RFT temperature determines the therapeutic effect. The higher the temperature, the greater the tissue damage and the greater the RFT range. RFT through the FR can permit an optimal increase in RFT temperature that can increase the therapeutic effect without affecting V1 and V3 division nerves.

This study has some limitations. First, the cohort size is small. At present, the sample size is small, but we will gradually increase the number of patients later at a later time. Second, there may be acquiescence bias or response bias. For ethical considerations, this study compared the 2 treatment groups without setting up a sham group. Third, the punctures under the more commonly used C-arm imaging guidance deserve to be evaluated in the future.

Conclusions

CT-guided RFT through the FR and FO are both effective minimally invasive treatments for V2 TN that can relieve pain effectively. Both have the characteristics of simple operation, good treatment effect, and low recurrence rate. Maxillary nerve RFT through the FR is safer and has a lower incidence of complications than RFT through the FO. In the early postoperative period, using RFT-FR, quality of life is more improved than after RFT through the FO, and the positioning accuracy is also better. This can increase patient compliance. It is a safe and effective choice for the treatment of V2 TN. In the next step, we will conduct further research in a prospective study.

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Authors' Contributions

Drs Tao Hong and Peng Yao designed and conducted the study, including patient recruitment, data collection, and data analysis. Dr Hongxi Li collected the date. Dr Yuanyuan Ding prepared the manuscript draft. Dr Tao Hong analyzed the data. All authors approved the final manuscript.

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