

Prospective Study

e Computed Tomography-Guided Radiofrequency Ablation for Glossopharyngeal Neuralgia: Comparison of Cervical Computed Tomography Angiography, Transverse Process of Atlas, and Styloid Process Localization to Styloid Process Localization Alone

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Background: Glossopharyngeal neuralgia (GPN) is a condition that causes simultaneous headache and facial pain. The treatment for GPN is similar to the treatment for trigeminal neuralgia. Craniotomy microvascular decompression (MVD) or radiofrequency (RF) therapy is needed if conservative treatment with oral drugs fails. Therefore, the choice of radiofrequency therapy target is essential when treating GPN. However, finding the glossopharyngeal nerve simply by styloid process positioning is challenging.

Study Design: Prospective, clinical research study.

Setting: Department of Anesthesiology and Pain Medical Center, Jiaxing, China.

Objective: To compare the clinical effects of computed tomography (CT)-guided RF treatments on GPN when the triple localization of cervical CT, the transverse process of the atlas, and the styloid process is used to those achieved when the treatments are guided by the styloid process alone.

Methods: From August 2016 to December 2019, 19 cases of GPN neuralgia were treated by radiofrequency under the guidance of CT guided by the styloid process only. (These patients comprised the single localization (SL) of styloid process group, in whom the target of the RF treatments was the posterior medial side of half of the styloid process). From January 2020 to December 2022, 16 cases of GPN were treated by RF under the guidance of CT with cervical CTA (CT angiography), the transverse process of the atlas, and the styloid process. (These patients were placed in the TL group, in whom the target of RF therapy was the gap between the internal carotid artery and the internal jugular vein behind the horizontal styloid process at the lower edge of the transverse process of the atlas). Two percent lidocaine was injected subcutaneously at the needle insertion site, and a stylet with a 21-gauge blunt RF needle (model: 240100, manufacturer: Englander Medical Technology Co., Ltd.) was slowly advanced toward the target. After that, an RF probe was introduced, then low (2 Hz)- and high (50 Hz)-frequency currents of the RF instrument (model: PMG-230, Canada Baylis company) were applied to stimulate. A successful test was defined as a 0.5-1.0 mA current stimulation that could induce the original pain area in the pharynx, the inner ear, or both, without any abnormal irritation of the vagus or accessory nerves. If the first test was unsuccessful, then in the SL group, the needle tip's position was adjusted to the distal end of the styloid process, and in the triple localization (TL) group, the needle tip depth's was fine-tuned. A continuous RF treatment was given after a successful test. The RF temperature was 95°C for 180 seconds. The time that the first puncture reached the target, the puncture paths, the success rate of the first test, the time that the glossopharyngeal nerve was found, the frequency of adjustments to the position of the RF needle, the incidence of intraoperative and postoperative complications, and the therapeutic effects were recorded.

etc.) that might pose a conflict of interest in connection with the submitted article.

Ethics Approval and Consent to Participate: Institutional review board/ethics committee approval was obtained from the institutional review board of the Jiaying First Hospital.

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Results: There were no significant differences in demographic data such as age, medical history, lateral classification, and pain score between the groups, but the TL group had a higher proportion of women than did the SL group. All patients' puncture targets were identified according to the designed puncture path before the operation. There was no difference between the 2 groups in the time of the first puncture to the target (5.05 ± 1.22 vs. 5.82 ± 1.51 , $P = 0.18$), and the designed puncture depth (3.65 ± 0.39 vs. 4.04 ± 0.44). The difference in puncture angles (13.48 ± 3.56 vs. 17.84 ± 3.98 , $P < 0.01$) was statistically significant, and in 8 cases in the SL group, the glossopharyngeal nerve could not be found after 60 minutes of testing, so the RF treatment was terminated. Meanwhile, this problem occurred in only 2 cases in the TL group. There were 3 cervical hematoma cases and 2 cases of transient hoarseness and cough in the SL group, whereas the TL group had, respectively, 0 and one cases of those issues. There was no death in either group.

Limitations: More clinical data should be collected in future studies.

Conclusion: When using RF as a treatment for GPN, the glossopharyngeal nerve is easier to find by using the triple positioning of the cervical CTA, the transverse process of the atlas and the styloid process as the target to determine the anterior medial edge of the internal carotid artery behind the styloid process at the level of the lower edge of the atlas transverse process. The glossopharyngeal nerve is more difficult to locate when only the posterior medial edge of the styloid process is targeted. The single-time effective rate of 180 seconds of RF ablation at 90°C for GPN can reach 87.5% (14/16), suggesting the treatment's potential for clinical application.

Key words: Glossopharyngeal neuralgia, radiofrequency ablation, CT-guided, styloid process, atlas transverse process, cervical CTA

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Glossopharyngeal neuralgia (GPN) is a rare condition that causes headache and facial pain. Varrasi et al found that GPN's annual incidence rate was 0.7 ~ 0.8/100,000, accounting for only 0.2 ~ 1.3% of head and face pain and about one percent of trigeminal neuralgia (1-3). GPN usually occurs as short-term paroxysmal acute pain in the branch area of the glossopharyngeal nerve. The nature of the pain and the treatment recommended for the condition are the same as those of trigeminal neuralgia (4). Oral administration of carbamazepine, gabapentin, and other antiepileptic drugs is often the first-line treatment (5). However, when oral administration is inefficient or the side effects of the drugs are intolerable, surgical treatments, such as craniotomy microvascular decompression (MVD), can be used (6,7). The limitation of MVD is that can treat only classic GPN caused by vascular compression of glossopharyngeal nerve roots, according to the International Classification of Headache Disorders. Furthermore, MVD has many complications and even fatal risks (8-10).

Compared to MVD, radiofrequency (RF) therapy is safe, convenient, and low-cost (11,12). However, the glossopharyngeal, vagus, and accessory nerves exit the skull through the jugular foramen, and the angle range is large at the posterior edge of the styloid process.

Therefore, finding the glossopharyngeal nerve simply by styloid process positioning is difficult. This study evaluated the clinical effects of computed tomography (CT)-guided RF therapy that used angiography (CTA) on glossopharyngeal neuralgia. We compared the effects of RF therapy that used the triple location of the transverse process of the atlas and the styloid process to those of therapy that used the styloid process alone.

METHODS

The Research Object

From August 2016 to December 2022, thirty-five patients, including 19 men and 16 women, aged 36 ~ 93 (62.1 ± 12.4) years, with a history of 3 ~ 56 (24.0 ± 13.9) months, were diagnosed with glossopharyngeal neuralgia and received RF therapy in the authors' pain department. The left and right sides ranked 20/15. All patients reported lightning-like pain in the pharynx or the inner ear, and the pain was easily induced when swallowing or speaking and radiated to the base of the tongue, the mandible, and the ear temporal regions. The pain lasted for several seconds to several minutes, and there was a completely painless interval after the attack. The visual analog scale (VAS) score was 5-10, averaging 7.3 ± 1.3 . Touching facial skin, lips, buccal

mucosa, teeth, and gums did not induce pain attacks. Administering topical anesthesia with lidocaine to the pharynx could make the pain disappear for several hours. All patients were treated conservatively with oral carbamazepine, gabapentin, pregabalin, or oxazepam before the operation, and the oral drugs could reduce the degree and frequency of pain. Six patients reported it was difficult to tolerate the vertigo caused by the oral medication. Five patients had undergone craniotomy and microvascular decompression before the visit. The Hospital's Medical Ethics Committee approved the research plan, and the patients and their families signed informed consent forms.

Preoperative Preparation and Patient Grouping

Before the operation, brain MRI and CT scans of the head were performed to exclude the possibility of occupying lesions of the cerebellopontine angle. Routine pre-sample examinations such as electrocardiograms (ECG), chest CT scans, routine blood work, coagulation function tests, and biochemical analyses were conducted to confirm that patients showed no suppurative infections, coagulation dysfunctions, severe cardiovascular or cerebrovascular diseases, cognitive or language communication impairments, or other contraindications for RF treatment. Before treatment, the treatment principle, specific methods, and the risks of CT-guided percutaneous RF treatment for glossopharyngeal neuralgia were explained to patients and their families, and all patients signed an informed consent form. An RF therapeutic instrument (model: PMG-230, Kimberly-Clark Baylis) was applied in the study. No. 7 special blunt RF puncture needles (patent number: ZL2021 2 2310301.2) with a length of 10 cm and a bare end of 5 mm were on standby, as was a corresponding length of RF electrode. We prepared a vital sign monitor and rescue drugs such as atropine, lidocaine, and adrenaline. Before the operation, a trocar was placed in the vein of the affected upper limb to open the intravenous infusion channel for standby. Patients fasted for 4 hours, and the cervical area to be treated with RF was marked.

Patients were divided into 2 groups according to the period of previous treatment: 19 cases before December 2019 were treated according to the styloid process (single localization of the styloid process [SL] group), and 16 cases after January 2020 were treated by the triple localization of cervical CTA, the transverse process of the atlas, and the styloid process (triple lo-

calization [TL] of cervical CTA, the transverse process of the atlas, and the styloid process group).

CT-Guided Positioning and Puncture Operation Method

The operation method used in the SL group was as follows:

After entering the CT treatment room, the patient was told to lie on the healthy side of the CT operating table. The patient's blood pressure, ECG, and pulse oxygen saturation were routinely monitored. Oxygen was given through a nasal catheter, and a CT positioning grid was placed below the earlobe. In the cervical vertebra mode, head positioning images were taken, the mastoid region was scanned in an axial direction with a thickness of 2 mm, and the obtained images were played back. In the SL group, the puncture level was the middle point of the styloid process. The puncture path was designed so that the first puncture target was the medial edge behind the middle point of the styloid process. The second puncture target was 5 mm from the middle point of the styloid process to the distal end, and the third puncture target was 5 mm from the distal end, and so on, until the posterior medial edge of the styloid process tip, the *n*th target point. A straight line outward and upward from the target point was established, and the puncture point was the intersection point of the line and the skin in the cervical region. We then measured the puncture depth (the distance from the puncture point to the target point) and puncture angle (the angle between the line and sagittal plane) (Fig. 1), moved the CT bed to the designed puncture level, and marked the puncture point by combining the positioning grid and positioning laser line (Fig. 2). A sterile hole towel was laid for routine disinfection. After 2 mL of lidocaine was used for local anesthesia on the skin at the puncture site, a blunt 7-point special RF needle with a length of 10 cm and a bare end of 5 mm was used to puncture the target according to the designed path under CT guidance (Fig. 3), and CT scanning was used for 3-dimensional reconstruction observation and confirmation (Fig. 4). Then we used an 0.5-1.0 mA current to conduct an electrical stimulation test with the frequencies of 50 Hz and 2 Hz, which could induce a tingling or an abnormal sensation in the original pain attack area of the ipsilateral pharynx, to find the glossopharyngeal nerve. A successful test was defined as the 0.5-1.0 mA current stimulation that could induce the original pain area in the pharynx, the inner ear, or both, without any abnormal irritation of



Fig. 1. The puncture path was designed by only styloid process positioning. (The first target was the posterior medial margin of the styloid process's midpoint).

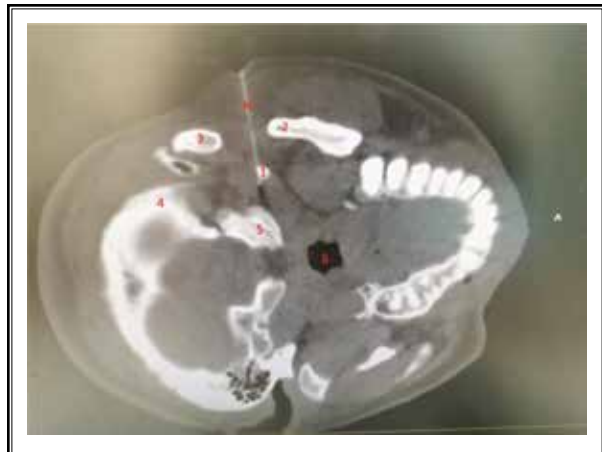


Fig. 3. In accordance with the puncture path designed by the styloid process, the RF puncture needle punctured the first target point (the posterior medial edge of the styloid process's midpoint) under the guidance of CT.



Fig. 2. The patient was lying on the healthy side of the body. After CT scanning and positioning, the puncture point was marked in the patient's cervical area with the positioning grid.

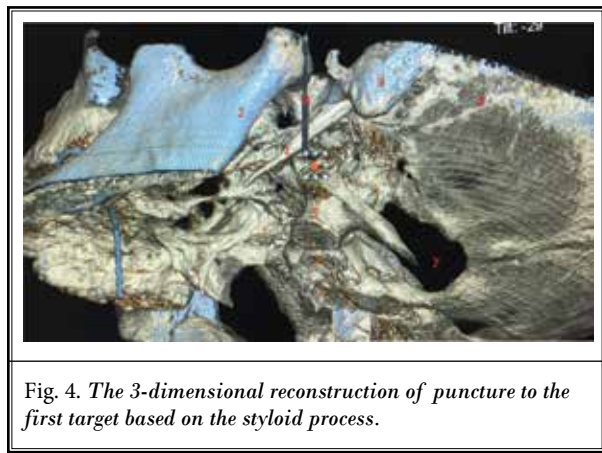


Fig. 4. The 3-dimensional reconstruction of puncture to the first target based on the styloid process.

the vagus and accessory nerves. If a successful test was achieved, the patient had no nausea, sudden change of unintentional heart rate by more than 20 beats per minute (BPM), and no rhythmic jitter of shoulder muscles. Then the patient received RF ablation treatment at 90°C for 180 seconds (13-15) (Fig. 5). If stimulation could induce neither a tingling sensation in the original ipsilateral pain attack area of the pharynx nor inner ear paresthesia, or if the patient had nausea, a heart rate that slowed down or sped up by more than 20 BPM, or a rhythmic jitter in the shoulder muscles,

an adjustment of the needle was made to the second, third, or next puncture target, accordingly, and then electrophysiological tests were conducted until successful before RF ablation. The test was considered failed if the time of repeated tests exceeded 60 minutes, and the patient then received 3 mL of 0.25% ropivacaine as a nerve block. In that situation, the patient would have the RF treatment on another day.

TL Group Operation Method

The patient underwent CTA-assisted pre-positioning one day before the operation. The pre-positioning consisted of downward CTA vessel imaging on the healthy side, finding the CT plane at the lower edge of the transverse process of the atlas, selecting the punc-



Fig. 5. The image of RF ablation after a successful test.

ture target at the posterior inner side of the styloid process and the gap between the internal jugular vein and internal carotid artery on this plane, and then pulling a straight line from the target to the upper outside. The puncture point was the intersection of this line and the skin in the cervical region. The distance between the puncture point and the target point (puncture depth) and the angle between the puncture route and the sagittal plane (puncture angle) were measured with a software ruler (Fig. 6). After the patient entered the CT operating room, her or his mastoid region was scanned by CT positioning again to find the corresponding level of the puncture path designed under the preoperative CTA. The puncture target and path were marked again regarding the original design path (Fig. 7). Because the patient's body could not be in the same position as in preoperative CTA, the puncture angle and depth of this design path might have been slightly different from those of the designed puncture path in the preoperative CTA image. Therefore, the positioning grid was used to mark the puncture point on the skin. According to the designed puncture path under CT guidance, the RF needle punctured the gap between the internal carotid artery and the internal carotid vein at the back of the horizontal styloid process at the lower edge of the transverse process of the atlas (Figs. 8-10). The electrophysiological test confirmed the glossopharyngeal nerve's location and avoided the vagus nerve. After the completion of the electrophysiological test, the RF treatment was performed. If paresthesia was detected in the glossopharyngeal nerve, the depth of the

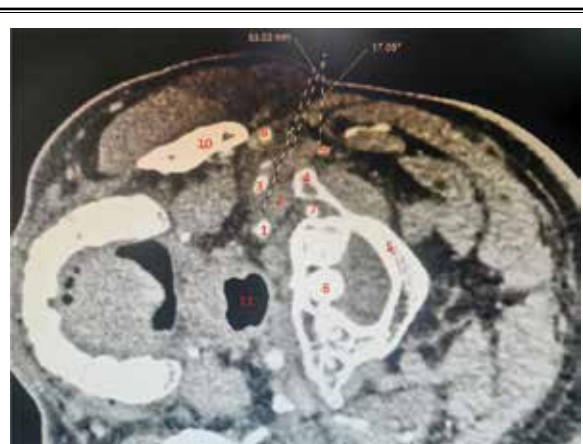


Fig. 6. The puncture path design under CTA.



Fig. 7. The median puncture's diameter was designed under the preoperative CTA image, and the puncture path was confirmed again in combination with positioning deletion.

puncture needle was adjusted within 5 mm above and below the target along the internal carotid artery and vein space. If the glossopharyngeal nerve paresthesia was not present within 60 minutes, a nerve block was performed, and the RF treatment was abandoned.

The patient's vital signs were monitored during RF, and the patient was instructed to make the same sound continuously. Once the tone made by the patient changed, the RF paused immediately. The needle tip's position was then adjusted by conducting the electrophysiological test. The RF treatment (90°C, 180 seconds) was performed if the tone did not change. After RF ablation, the patient was asked whether the original pain

had disappeared and was instructed to check whether swallowing induced the original pain. If swallowing could still induce the initial pain attack, the needle tip's position was adjusted, and an electrophysiological test was conducted again before the RF ablation treatment. If the glossopharyngeal nerve could not be identified within one hour, the RF treatment was canceled, and a nerve block was applied. The patient was scheduled to receive the RF operation another day.

The patient's vital signs were monitored closely during the treatment, and the patient's reactions during puncture and RF were observed carefully. During puncture, we mainly observed the hematoma caused

by blood vessel injury (incorrectly penetrating the internal carotid artery and vein). Other complications included hypertension, arrhythmia, nausea, choking, hoarseness, and facial paralysis during RF treatment. If there were related symptoms, the operator stopped the treatment immediately and dealt with the symptoms to ensure the patient's safety. On the second day after the operation, the patient's pain was scored on the VAS, and the effect was evaluated based on the presence of paroxysmal GPN. An absence of GPN meant the treatment was considered effective. The treatment was considered invalid if the patient's pain did not improve significantly from before the operation to the second day after the operation. RF therapy was conducted again in such cases, and the VAS scores were re-evaluated one month afterward. The recurrence was followed up by telephone at 6, 12, and 24 months after the operation.

Statistical Analysis

All the research data were analyzed by SPSS® 26.0 (IBM®). The data of age, medical history, preoperative VAS score, puncture depth, puncture angle, and the time when the first puncture reached the target point showed normal distribution. The differences in population indexes between the 2 groups were compared by independent t-tests. The chi-square test was used to compare the first test's success rate. The rank sum test was used to compare the differences between the 2 groups in the number of needle tip replacements, the

time it took to find the glossopharyngeal nerve, and the VAS scores of one d and one M. The statistically significant difference was defined as $P < 0.05$.

RESULTS

Comparison of General Data Between the 2 Groups of Patients

There was no significant difference between the 2 groups in general data such as gender, age, course



Fig. 8. The RF needle's puncture to the target.

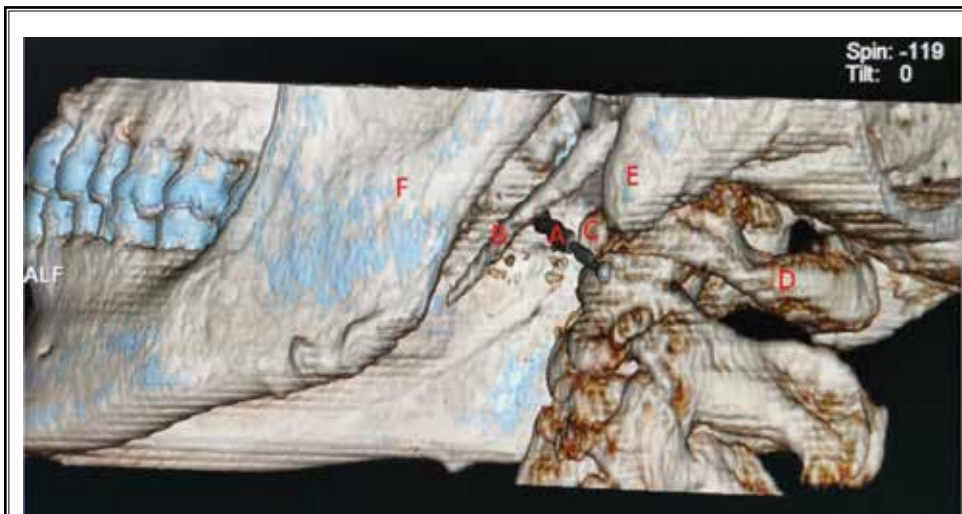


Fig. 9. Three-dimensional reconstruction of CT after a successful puncture.

of the disease, diseased side, and preoperative VAS score ($P > 0.05$), as shown in Table 1.

Comparison of Puncture Depth, Puncture Angle, Time of First Puncture Reaching the Target, the Positive Rate of the First Test, Adjustment Times, Test Time, and Rate of RF Therapy Cancellation Between the 2 Groups

The comparisons of puncture depth, puncture angle, time that the first puncture reached the target, positive rate of the first test, adjustment times, and test time between the 2 groups are shown in Table 2. The average puncture depth in the SL group was 6 mm shallower than that in the TL group. The puncture inclination angle was slightly smaller than the TL group's. The SL group had more instances

of needle adjustment and longer test times than the TL group. In the end, 8 cases in the SL group involved failure to find the glossopharyngeal nerve after 60 minutes of the test, so those patients did not receive the first RF treatment and had another treatment instead, while the TL group included only 2 such cases.

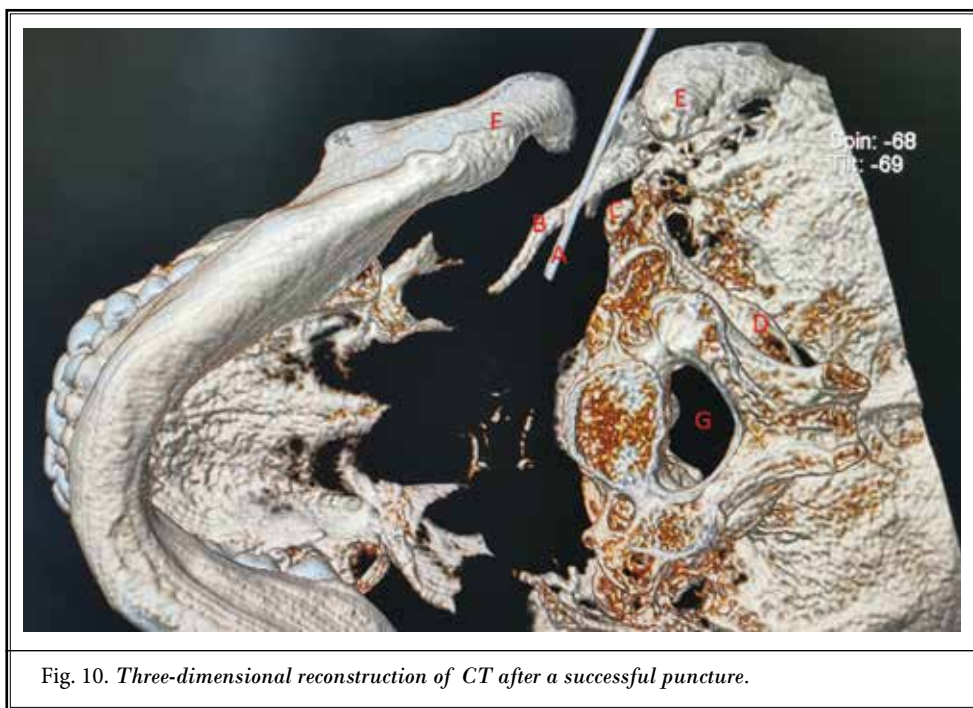


Fig. 10. Three-dimensional reconstruction of CT after a successful puncture.

Table 1. Comparison of general data of 2 groups of GPN patients.

Group	Numbers	Gender (M/F)	Age (Years, $\bar{x} \pm s$)	Sides (L/R)	Course (Month, $\bar{x} \pm s$)	VAS Score Before Treatment ($\bar{x} \pm s$)
SL	19	14/5	59.53 \pm 12.95	9/10	23.89 \pm 14.79	7.32 \pm 1.25
TL	16	5/11	65.06 \pm 11.38	11/5	24.18 \pm 13.31	7.29 \pm 1.31
χ^2/t	-	6.30	1.354	1.62	0.06	0.05
P	-	0.012	0.185	0.17	0.95	0.96

Note: GPN is a patient with glossopharyngeal neuralgia; VAS is a visual analog scale score.

Table 2. Puncture depth, puncture angle, time spent reaching the first puncture target, positive rate of the first test, adjustment times, and test times of the 2 groups of patients.

Groups	Puncture Depth	Puncture Angle	Time Spent Reaching First Puncture Target	Positive Rate of First Test	Adjustment Times	Test Times
SL (n = 19)	3.65 \pm 0.39	13.48 \pm 3.56	5.05 \pm 1.23	2/19	6.37 \pm 3.08	50.16 \pm 16.42
TL (n = 16)	4.04 \pm 0.44	17.84 \pm 3.98	5.82 \pm 1.51	7/16	1.24 \pm 1.30	17.88 \pm 17.81
$t/z/\chi^2$	2.84	3.47	1.42	6.06	4.27	3.64
P	< 0.01	< 0.01	0.18	0.02	<0.01	< 0.01

The 2 Groups of Patients During and After the Operation Complications and Treatment Effects

In the SL group, 4 patients had shoulder twitches, nausea, or coughing reactions during the test, and 3 patients had bradycardia during the electrophysiological test, which disappeared after the needle tip's position was adjusted. One patient in the TL group developed bradycardia during the test. After RF thermocoagulation at 90°C for 180~300 seconds, the glossopharyngeal neuralgia disappeared postoperatively. The patients experienced abnormal choking sensations in the affected tongue base and pharynx but did not have taste loss or dry mouth. Transient hoarseness and cough occurred in 2 patients in the SL group and one in the TL group. All cases of these reactions disappeared within one week. There were 3 cases of cervical hematoma in the SL group but none in the TL group. Neither group showed instances of facial paralysis, shrug disorder, cerebral infarction, or death. No patients suffered from hypoxemia under oxygen inhalation during the operation. However, patients in both groups had hypertension during the operation (the ascending value was more than 20% of the baseline in 5 patients in the SL group and 4 patients in the TL group). Administration of 12.5 ~ 75 mg urapidil hydrochloride was deployed in batches.

There were 5 and 3 respective patients in the SL group who received the second and third RF treatments several days later, and 2 patients in the TL group received the second RF therapy. When these therapies were combined with repeated treatment, the pain scores of the SL group and TL group were, respectively, 1.32 ± 1.00 and 0.41 ± 0.62 ($t = 0.28$, $P < 0.01$) after one month's follow-up. All patients in the SL group were followed up for 24 months, and one patient relapsed in 19 months. Patients in the TL group were followed up for fewer than 24 months, and there was no recurrence.

DISCUSSION

The nature and pathogenesis of GPN pain are similar to those of trigeminal neuralgia, but the pain location is often confined to the glossopharyngeal nerve innervation area, and GPN's incidence rate is lower than that of trigeminal neuralgia. The term GPN was first used by Harris in 1921 to describe paroxysmal pain in the back of the tongue and the throat. Paroxysmal pain is a sudden pain that persists for a short term (lasting several seconds to tens of seconds (16).

Most cases of GPN are accompanied by vascular

compression of glossopharyngeal nerve roots, which leads to demyelinating changes (17). Secondary GPN is usually caused by pontine-cerebellar angle tumors or nasopharyngeal carcinoma involving the glossopharyngeal nerve. The diagnosis is relatively easy, based on the typical clinical manifestations of GPN (18). It is necessary to distinguish primary GPN from the pain of the mandibular branch of the trigeminal nerve. Because the glossopharyngeal nerve has branches that enter the trigeminal nerve's spinal nucleus, sometimes the pain range can extend to the distribution area of the trigeminal nerve or complicated with trigeminal neuralgia, which makes diagnosis difficult. A positive surface anesthesia test of the throat (one percent Dicaïne or 2% lidocaine can prevent the onset of pain for one to 4 hours after the throat receives surface anesthesia) is a standard differential diagnosis method.

The treatment for GPN is similar to the treatment for trigeminal neuralgia. Craniotomy microvascular decompression (MVD) or RF therapy is needed if conservative treatment with oral drugs fails. For definite diagnoses of GPN, MVD procedures are the most widely used treatment method in neurosurgery, except for oral antiepileptic drugs (for patients whose conditions are in the early-onset stage). However, MVD is risky and has many complications. Zhao et al retrospectively analyzed the clinical data of 12,239 patients with cranial nerve diseases who underwent MVD in the Department of Neurosurgery at the China-Japan Hospital from January 2008 to December 2015. In the Zhao et al report, 15 patients died after the operation, showing a mortality rate of 0.12% (15/12,239), and the incidence of intracranial hemorrhage after MVD was as high as one percent (19).

Moreover, because the nerve and blood vessels in the posterior margin of the styloid process are closely arranged, it is not appropriate to use a destructive chemical blocker such as anhydrous alcohol or carbolic acid to treat GPN. The distribution of liquid medicine after injection is difficult to control, which increases the risk of damaging the adjacent vagus and accessory nerves. Damage to the vagus nerve will result in long-term dysphagia, choking cough, and hoarseness, thus inducing new pain syndromes in patients. In addition, accidental injections of anhydrous alcohol into the static internal arteries and veins will cause cerebral infarction and myocardial infarction.

RF therapy means physical damage, and the controllability of the thermal coagulation range is significantly higher than that of the injection of

chemical-damage drugs. Therefore, Huang et al (20) propose that as safer and more selective RF technology develops, neurochemical lesion-blocking therapy will gradually be replaced by other, safer technologies.

Because of the special anatomy involved in GPN, the intracranial ganglia or nerve trunk in the craniotomy tunnel (like the target of trigeminal neuralgia) are unsuitable for RF therapy. Therefore, the choice of RF therapy target is essential in GPN treatment. The glossopharyngeal nerve is the ninth cranial nerve, originating from the medulla oblongata. It exits the cranial cavity through the jugular foramen with the vagus and accessory nerves in the pontine cistern. The superior and inferior cervical ganglia of the glossopharyngeal nerve are located in the jugular foramen. Although the jugular foramen is a natural bony symbol, the glossopharyngeal nerve, vagus nerve, and accessory nerve are accompanied by craniotomy in the jugular foramen, and the distance is the closest. In addition, all 3 nerves are close to the internal jugular vein in the jugular foramen. Thus, if the ganglion is used as the target of RF treatment, as in the RF treatment for trigeminal neuralgia, it is difficult to avoid damaging the internal jugular vein, vagus nerve, and accessory nerve. When Lazorthes et al (21) used extracranial ganglion ablation to treat GPN in the last century, the RF treatment targeted the glossopharyngeal ganglion of the jugular foramen. However, using the jugular foramen as the puncture target to avoid the internal jugular vein and internal carotid artery is challenging, as is distinguishing the glossopharyngeal nerve from the vagus nerve and accessory nerve for highly selective RF treatment. Complications caused by cervical hematoma and vagus nerve injury, such as hoarseness and choking during drinking, happen commonly. Therefore, the existing RF technology for treating GPN has not been effective in the clinic.

Notably, the target of previous RF treatments of the glossopharyngeal nerve was usually selected in the styloid process after the glossopharyngeal nerve emerged from the jugular foramen. However, this segment of the glossopharyngeal nerve has a large degree of positional freedom, so the styloid process alone was used as a bone reference mark for the RF treatment for GPN, and the treatment target was selected at its posterior margin. For that reason, there were multiple targets, and the "trial and error" test was carried out on each target in turn, which not only led to a low positive rate (the probability of finding the glossopharyngeal nerve) after puncturing a single

target successfully but also required a long time investment to find the glossopharyngeal nerve, and the risk of hematoma after the repeated puncture of multiple targets was doubled. Ren et al found that more than one-third of GPN patients had to receive repeated RF treatments to achieve a good analgesic effect (22). Our study also found that the positive rate of the first test in the SL group was only 10.53% (2/19). Even after the target position was adjusted an average of 6 times for 60 minutes, the glossopharyngeal nerve could not be located in 42% (8/19) of the patients. Repeated adjustments of the needle puncture operation also increased the incidence of cervical hematoma (15.8%, 3/19).

Together, the posterior medial styloid process and a lower horizontal edge of the transverse process of the atlas comprise the best target for the RF treatment for GPN. The choice of points and the design of the puncture path, combined with CTA, can significantly improve the accuracy of therapeutic treatments. In recent years, anatomical comprehension of the glossopharyngeal nerve and jugular foramen has increased. As sectional image anatomy has progressed, the course of the glossopharyngeal nerve at different levels of the neck has been understood completely (23,24). At the level of the lower edge of the transverse process of the atlas, the glossopharyngeal nerve trunk is located inside the styloid process, in front of the internal carotid artery, and outside the styloid pharyngeal muscle. At the level of the lower edge of the transverse process of the atlas, the glossopharyngeal nerve gradually extends from the internal carotid artery and vein space. The nerve runs on the posterior medial side of the styloid process, the anterolateral side of the internal carotid artery, and the anterolateral side of the stylopharyngeal muscle. Both the transverse process of the atlas and the styloid process are used as bone markers. In addition, the internal carotid artery and stylopharyngeal muscle are used to mark blood vessels and soft tissue, respectively (25-27). Therefore, whether the imaging is guided by CT or ultrasound, the comprised styloid process and transverse process of the atlas can be the best target for RF treatments on the glossopharyngeal nerve. The experiments in the SL group, which used only the styloid process as the puncture target, also confirmed that when the glossopharyngeal nerve was found, it was mostly located in the styloid process and at the lower edge of the transverse process of the atlas.

Moreover, when CTA is used, not only can the styloid process and the transverse process of the atlas be seen, but the internal carotid artery and internal

jugular vein may also be visible to the physician. Therefore, the triple positioning of cervical CTA, the transverse process of the atlas, and the styloid process may theoretically lead to more accurate imaging than the positioning of the posterior medial edge of the styloid process alone. It was also observed that the rate of positive searches for the glossopharyngeal nerve was higher in the TL group than in the SL group (7/16 vs. 2/19, $\chi^2 = 6.06$, $P < 0.01$), and the TL group's total test time (50.16 ± 16.42 vs. 17.88 ± 17.81 min, $P < 0.01$) was lower than the SL group's. These results may suggest that with the assistance of CTA, it is easier to identify the glossopharyngeal nerve prior to RF treatment by using the triple positioning of the lower edge of the transverse process of the atlas and the posterior medial side of the styloid process.

A blunt puncture needle should be used in RF of the glossopharyngeal nerve to reduce the likelihood of cervical hematomas. When the physician prepares to puncture the glossopharyngeal nerve for the RF procedure, sharp puncture needles should be avoided. To prevent neck hematomas, gentle, slow force should be used when inserting needles because static internal arteries and veins are punctured easily. Since the upper segment of the glossopharyngeal nerve is in the gap between the internal carotid artery and the internal jugular vein, the horizontal glossopharyngeal nerve at the lower edge of the transverse process of the atlas is transferred from the gap between the internal carotid artery and the internal jugular vein. The nerve also clings to the front wall of the internal jugular artery. If the RF puncture needle aims to reach the glossopharyngeal nerve, it will inevitably cling to the internal jugular artery and vein. A sharp puncture needlepoint close to the blood vessel will pose a greater risk of damaging

the blood vessel wall and causing a neck hematoma. This risk is especially true of CT-guided styloid punctures, which involve no preoperative CTA to show the location of blood vessels as a reference, meaning that the internal carotid artery and vein cannot be clearly displayed in CT images during an operation, potentially increasing the risk of the accidental piercing of blood vessels.

Moreover, when we adopted RF treatments via the extracranial nerve to treat hemifacial spasms and Meige's syndrome, we found that the sharp puncture needle could also cause uncontrollable facial nerve punctures and cutting injuries, which made controlling the degree of facial paralysis difficult (28-31). Therefore, we developed a blunt RF puncture needle for neurological RF (Fig. 11, patent number: ZL2017 2 1635823.7). The insulation layer of the needle body is white, the printing depth is marked, and the needle tip is round and blunt. The blunt needle may preclude uncontrollable cutting damage to the quasi-RF nerve tissue and reduce the likelihood of causing cutting injuries to tissues or blood vessels along the puncture path, thus posing less risk of forming a hematoma. In addition, after 2020, we adopted CTA-assisted triple positioning technology of the styloid process and the transverse process of the atlas. With the modified technology, the specific positions of internal carotid arteries and veins on the puncture path can be clearly defined, and the puncture process can be targeted to avoid cervical hematomas caused by puncture injuries to blood vessels.

The protection of the vagus nerve and accessory nerve during RF depends mainly on the electrophysiological test and close observation of patients during the RF procedure. If the patient's shoulders jitter during



Fig. 11. *Special puncture needle for cranial-nerve RF.*

the 1 mA low-frequency (2 Hz) current test, the needle tip is too close to the accessory nerve. If the patient experiences choking and nausea, with or without a slow heart rate, during the 1 mA high-frequency (50 Hz) current test, the needle tip is too close to the vagus nerve. To avoid nerve damage, it is then necessary to adjust the needle tip's position before testing to ensure enough distance between the needle tip and the vagus/accessory nerves. Even if the pre-RF test confirms that the needle tip is safely far enough from the vagal and accessory nerve, the patient's reaction should be closely observed throughout the RF procedure. During RF, the physician should ask the patient whether she or he suffers nausea or coughing and, throughout ECG monitoring and care, whether the patient's heart rate is changing. The patient should be instructed to repeat the same sound during the RF ablation. Once the patient's tone of voice changes, the should immediately stop RF, inject saline solution into the patient's mouth, and ask her or him to swallow. To determine if the vagus nerve is affected, the operator should observe whether the patient chokes on any water.

This study found 5 cases of intra-operative voice changes and 3 cases of postoperative hoarseness and dysphagia, but all patients so affected recovered within a week, which might have been due to the heat conduction to the vagus nerve during RF ablation. Since the RF procedure was ended in a timely manner, no irreversible damage to the vagus nerve occurred. In addition, because the posterolateral side of the stem process root is the stem foramen, the position of the facial nerve that leads out of the skull, it was selected as the target in treatments for hemifacial spasms in our previous studies (28-31). Placing a puncture needle near the styloid process root may damage the facial nerve and cause facial paralysis, so physicians using these needles should avoid that area.

Limitation

The primary limitations of this investigation come

from its restricted sample size and reliance on data derived from a single center. Nevertheless, we remain optimistic that the triple positioning technique as detailed in our report will be implemented by a broader cohort of professionals in the field. A vital objective is to assess the feasibility and safety of this approach in the future.

CONCLUSION

In conclusion, it is challenging to treat GPN with RF therapy when the target is set by only trailing the edge of the styloid process as a reference because the glossopharyngeal nerve's position has great variability at that location. Determining the RF target for GPN by combining CTA, the transverse process of the atlas, and the styloid process before the operation effectively improves RF therapy's efficiency. Our study has some limitations. Due to the limited incidence of GPN, the sample size in this study is small, and the observations do not constitute a multicenter, randomized, controlled trial. Nevertheless, we hope our GPN treatment strategy can be tested and verified in future clinical practices.

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Authors' Contributions

Huidan Lin, Bing Huang, and Xiangming Fang had the original idea for the manuscript and collected the data. Chunxiao Wang, Ying Ma, Yongqing Liu, and Xianghong Liu analyzed the data. Huidan Lin reviewed the literature for the introduction and drafted the manuscript. Bing Huang revised the manuscript. Xiangming Fang assisted in drafting the manuscript, revising the text, and approving the final manuscript. All authors read and approved the final manuscript.

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