Predictors of response for percutaneous balloon compression for the treatment of recurrent trigeminal neuralgia following surgical procedures: a retrospective study

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Research Article

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Abstract

Recurrent trigeminal neuralgia (TN) after surgical procedures can be rather difficult to treat, and standardized treatment measures are not available yet. It is unclear whether percutaneous balloon compression (PBC) can be used as the preferred surgical treatment for postoperative recurrent TN. To determine the efficacy of PBC and identify the predictors of response of PBC for the treatment of recurrent TN following TN-related surgeries, we retrospectively collected and analyzed the data of patients with recurrent TN following surgical treatments who underwent PBC under three-dimensional computed tomography (3D-CT) guidance at the department of Pain Management of Beijing Tiantan Hospital, Capital Medical University from January 2018 to January 2022. We found, within one month after PBC, the total efficacy of PBC on recurrent TN following TN-related surgeries was 86.7%. Based on the effectiveness of PBC one month postoperatively, patients were divided into the effective group (130, 86.7%) and the ineffective group (20, 13.3%). Fourteen (10.8%) patients in the effective group had undergone RFT before, which was significantly lower than that in the ineffective group (6, 30%, p = 0.02). In the crude, adjust I and adjust II models, previous RFT was considered to be a significant predictor of poor outcome at 1 month's follow-up (non-adjusted, OR 0.28; adjust I, OR 0.28; adjust II, OR 0.30, respectively). Thus, PBC was found to be a moderately effective and safe treatment for recurrent TN after TN-related surgery. However, previous RFT procedure may predict a slightly worse outcome after PBC.

Background

Trigeminal neuralgia (TN) is a unilateral, sudden, recurrent pain which is confined to the distribution of the trigeminal nerve [1]. The incidence rates of TN ranged between 5.9 and 12.6 per 100,000, with most of the cases occurring after 50 years of age [2]. Pharmacotherapy is generally the mainstay of treatment of TN. However, for those patients refractory to drug therapy, surgical strategies, including microvascular decompression (MVD), partial sensory rhizotomy (PSR), radiofrequency thermocoagulation (RFT), percutaneous balloon compression (PBC), gamma knife radiosurgery (GKRS) and glycerol rhizotomy (GR) are effective alternatives [3].

Nonetheless, each surgery results in a certain number of recurrences. A meta-analysis based on 8,172 surgery patients proved that the pooled recurrence rate was 9.6% for MVD, 12.4% for PSR, 11.9% for RFT, 12.3% for PBC and 20.9% for GKRS [4]. Another study described the acute pain relief (APR) after GR was 73% and pain recurrence rate was 21% within 5 years [5]. Recurrent TN after surgery often have long-term, repeated severe pain, which may easily cause anxiety and depression and can exert a negative impact on the quality of life [6]. Unfortunately, it can be quite difficult to treat, and treatment measures have not been standardized.

PBC has been an acknowledged alternative extensively used to treat TN patients with a relatively high pain relief rate [7, 8]. Some centers also reserve PBC for the patients who suffer recurrence following previous surgical procedures. Xu et al. reported that after PBC, complete symptomatic relief was obtained in 26 (92.9%) of the 28 TN patients with recurrent TN after MVD [9]. Chen et al. reported that, of the 32

patients with recurrent TN after PBC, 30 (93.8%) were immediately relieved of their neuralgia after repeated PBC [10]. In Fan et al.'s study, a total effective rate of 91.7% after PBC in 121 recurrent TN patients after MVD, RFT, PBC or GKRS [11]. However, some scholars consider PBC to be less effective in recurrent patients who have previously been treated with other surgical procedures [12, 13]. Chen et al. showed that for recurrent TN patients after MVD, a repeated MVD was a more effective procedure than PBC (95.6% vs.81%, $p < 0.05$) [14]. Montano et al. reported that only 81.81% of patients obtained an APR after PBC in 22 patients suffering one or more procedures before [15], which was much lower than those not following other surgical procedures. Similarly, Omeis et al. reported that, PBC had an 83% pain relief in a series of 29 relapsing patients after other surgical procedures [16]. However, the sample from above-mentioned studies were relatively small and rather inhomogeneous. It is not clear whether the analgesic effect of PBC on recurrent TN is worse than that of initial PBC. Additionally, there is a rare specific study to confirm potential prognostic factors which can be used before PBC to preoperatively predict the pain-free outcomes of recurrent patients. Therefore, the objective of this study was to determine the efficacy of PBC and identify the predictors of response of PBC for the treatment of recurrent TN following surgical treatments through a clinical study with a relatively large number of cases.

Methods And Analysis

The study protocol was approved by the Medical Ethics Committee of Beijing Tiantan Hospital, Capital Medical University before the retrospective collection of patient's data. Written informed consent from patients was exempted. The authors vouch for the accuracy of the data. This retrospective study analyzed the data of patients with recurrent TN following surgical treatments who underwent PBC at the department of Pain Management at Beijing Tiantan Hospital, Capital Medical University from January 2018 to January 2022. Demographic and perioperative data were retrieved from hospital information systems (HIS) medical records and follow-up data were collected from electronic records. Patients who met the following criteria were eligible for the study: (1) age >18 years; (2) diagnosed with TN in accordance with the third version of the International Classification of Headache Disorders (ICHD-3) [17]; (3) undergoing PBC operations; (4) history of previous surgeries for TN such as MVD, PSR, RFT, PBC, GKRS, GR, etc. The exclusion criteria were as follows: (1) bilateral TN; (2) diagnosis of secondary trigeminal neuralgia; (3) failure of puncture during PBC procedure; (4) untypical pear balloon shape; (5) patients with incomplete baseline data or follow-up data.

Surgical Technique

All procedures were conducted by experienced physicians. Under general anesthesia, surgery by laryngeal mask airway (LMA) was performed on the computed tomography (CT) scanning table with the patient in supine position. Blood pressure (BP), heart rate (HR), electrocardiogram (ECG), oxygen saturation and respiratory rate (RR) were continuously monitored. Atropine was used to treat bradycardia and unstable BP. The procedure was guided by 3D-CT. The point of entry into the skin was located approximately 2.5 cm lateral to the angle of the mouth. First, a 14-gauge tipped cannula was advanced parallel to the sagittal plane to avoid penetration of the oral mucosa. Based on the surgeon's clinical experience, the

cannula was advanced less than 7 cm, where the tip reached near the basal part of the midcranial fossa. Then, CT scan was performed. And on a dedicated workstation (GE AW VolumeShare 2, version aw4.4, Wisconsin, USA), automatic 3D reconstruction of the skull was completed in seconds to determine the exact location of the cannula and the foramen ovale (FO). According to its spatial relationship with the FO, the position of the cannula was adjusted until the needle had entered the FO. When the cannula was properly positioned, the stylet was withdrawn, a disposable balloon catheter (QKS-1850567, Qingyuan Medical Instrument) with a guiding wire was inserted into the cannula and then into the Meckel's cave. When the end of the balloon catheter passed the end of the cannula by approximately 1 cm, the guide wire was removed and 0.3-0.5 ml of non-ionic contrast agent (Omnipaque) was slowly injected into the balloon catheter to inflate the balloon. The balloon appeared to form the shape of a pear when positioned correctly into the FO. If satisfactory position or shape was not obtained, the balloon was deflated, the catheter was withdrawn, and the cannula was set back and readjusted according to the CT images. After visual confirmation of the balloon being positioned correctly was obtained, a total of 0.3-0.8ml of contrast agent was injected to compress the ganglion (the dosage of iohexol contrast agent was adjusted appropriately according to the volume of Meckel's cave). The compression lasted 90-180 seconds [18] (the time was adjusted according to factors such as balloon pressure, pain degree and patient age). After compression, the balloon was deflated and withdrawn. Then, anaesthesia was stopped. After emergence from anaesthesia and removal of LMA, patients were sent for post-anaesthesia care (Fig. 1).

Data collection and analysis

Preoperative, intraoperative and postoperative data from HIS and department follow-up database were collected. Preoperative data included the following: age, gender, Body Mass Index (BMI, weight in kilograms divided by the square of height in meters), comorbidities such as hypertension, diabetes mellitus (DM), heart disease, stroke, duration of disease (length of history before PBC), time to recurrence, baseline numerical rating scale (NRS) scores (0: no pain; 10: the most imaginable severe pain); carbamazepine dose pre-PBC, affected side of TN (left/right), distribution of pain, history of previous surgeries for TN, the number of previous surgeries, Barrow Neurological Institute (BNI) facial hypesthesia scale after the last surgery (Class I: no facial numbness; Class II: mild facial numbness and not bothersome; Class III: facial numbness and somewhat bothersome; Class IV: facial numbness and very bothersome). Intraoperative details of PBC procedure, such as vital signs fluctuation, including trigeminal cardiac reflex, operation duration, balloon shapes, compression time, balloon volume, intraoperative complications and side effects were all collected. The postoperative data included the NRS score immediately after PBC and postoperative complications or side effects. The effective rate was defined as cases with a reduction in pain intensity (NRS) >50% /total number of cases*100% within one month. According to whether it is effective within one month after PBC, the patients were divided into the effective group and the ineffective group. To improve clinical efficacy and safety, routine follow-ups were done on day 1, week 1, week 2, month 1, month 3, month 6 and 1 year postoperatively. Information on pain recurrence after PBC were collected from outpatient visits, wechat or telephone calls.

Postoperative complications such as herpes simplex, masseter weakness, facial numbness, facial swelling, diplopia, corneal anesthesia, infection or hematoma at puncture sites, intracranial hemorrhage or intracranial infection were collected. Once another surgical procedure was performed for recurrent or refractory TN after PBC, patient follow-up was stopped.

Statistical Analyses

IBM SPSS Statistics version 24 was used for statistical analyses. The patient data were assessed for normality using the Kolmogorov-Smirnov test. Continuous data following normal distributions were presented as means ± standard deviations (SDs) and were analyzed using t-test. Non-normally distributed continuous data were shown as medians and ranges and analyzed by Mann–Whitney U test or Kruskal-Wallis H test for intergroup comparisons. For categorical data, numbers (percentages) were calculated, and chi-squared test or fisher's exact was used to compare groups. Unadjusted and adjusted logistic regression models were used to determine the predictors of efficacy of PBC therapy for patients with recurrent TN. Confidence intervals (CIs) were set at 95%. A two-sided p value <0.05 was considered statistically significant.

Results

Characteristics of the Study Patients

Between January 2018 to January 2022, 151 patients with recurrent TN underwent CT-Guided PBC at the department of pain management. One patient who had the characteristic atypical pear-shaped balloon was excluded. Five patients (3.3%) had a history of allergy to carbamazepine. The other 145 patients were either refractory or intolerant to carbamazepine. Detailed characteristics of the 150 enrolled patients are shown in Table 1. The median age (range) was 66 (36, 87) years with a median disease duration (length of history before PBC) of 7 years. 130 (86.7%) patients were in the effective group and 20 (13.3%) patients were in the ineffective group. There were no significant differences in aspects of age, gender, BMI, comorbidities, duration of disease, time to recurrence, baseline NRS score, carbamazepine dose pre-PBC, affected side of TN, distribution of pain, and BNI facial hypesthesia scale after the last surgery between the two groups. Fourteen (10.8%) patients in the effective group only experienced RFT before, which was significantly lower than that in the ineffective group (6, 30%, p=0.019).

Operation Variables, Efficacy

The NRS score immediately after PBC in the effective group was much lower than that in the ineffective group (2 [range: 0,4] vs 7 [range: 6,8], P < 0.01). In the effective group, 121 patients (93.1%) experienced an immediate significant reduction in NRS score after the procedure, and the dose of the preoperative drug was gradually decreased. In 9 patients (6.9%), there was no significant decrease in NRS scores immediately after PBC, and these patients needed to continue treatment with medications. The pain began to gradually decrease at an average of 4 days (range 2 to 12 days) after PBC. They achieved pain relief within one month after PBC and stopped taking drugs. Among these 130 patients, 2 experienced

recurrence at 18 and 22 months after PBC procedure. Then both of them underwent repeated PBC and achieved pain relief instantly.

Within one month after PBC, the total efficacy of PBC on recurrent TN following TN-related surgeries was 86.7%. The efficacies of PBC after MVD alone, PBC alone, RFT alone, GKRS alone and GR alone were 90.9%, 77.8%, 70.0%, 92.9% and 83.3%, respectively. Besides, 88.9% patients underwent no less than 2 surgeries before achieving pain relief within one month after PBC.

Univariate analysis for recurrent TN outcome after PBC

Univariate logistic regression was used to determine the association between age, gender, BMI, comorbidities, duration of disease, time to recurrence, baseline NRS score, carbamazepine dose pre-PBC, affected side of TN, distribution of pain, history of previous surgeries for TN, BNI facial hypesthesia scale after the last surgery and TN outcome. The results showed that previous RFT was a significant predictor of poor outcome for recurrent TN following PBC (OR 0.28, 95%CI 0.09-0.85, *P*=0.03) (Table 3).

Relationship between preoperative variables and recurrent TN outcome after PBC in different models

We also employed multivariate logistic regression to demonstrate the association between previous RFT and TN outcome (Table 4). In the adjusting I (adjusting for age and gender) and II (adjusting for age, gender, BMI, comorbidities, duration of disease, time to recurrence, baseline NRS score, carbamazepine dose pre-PBC, affected side of TN, distribution of pain, BNI facial hypesthesia scale after the last surgery) models, the previous RFT was considered to be a significant predictor of poor outcome at 1 month's follow-up (adjust I, OR 0.28 ; adjust II, OR 0.30, respectively, both P <0.05).

Complications

Among the 20 patients who failed to respond to PBC, two underwent GKRS at 4, 5 weeks after PBC at other hospitals. The remaining 18 patients underwent RFT at our hospital. All of the 20 patients got satisfactory pain relief after GKRS or RFT.

There were no significant differences in incidence of trigeminal cardiac reflex, operation duration, balloon volume, compression time, herpes simplex and diplopia between the two groups. Patients developed herpes simplex on postoperative day 2-3, and the symptom lasted for 1 week. None of the patients in this study had facial swelling, corneal anesthesia, infection or hematoma at puncture site, intracranial hemorrhage, intracranial infection or death. Forty-five patients (34.6%) suffered masseter weakness in the effective group and 2 (10.0%) suffered that in the ineffective group (P=0.04, table 2). In addition, 119 (91.5%) patients developed facial numbness in the effective group compared to 4 (20.0%) in the ineffective group (P=0.00, table 2).

Discussion

The main finding of the present study is that, the total pain relief rate within one month after PBC under 3D-CT guidance for recurrent TN following surgical procedures was 86.7%, which was significantly lower than that of PBC for refractory TN in our previous study (95.7%) [19]. This result showed that, previous surgical treatments may reduce the chance of pain relief and increase failure rate. There were several small case series studies reporting the pain relief rate of PBC guided by C-arm for the treatment of recurrent TN ranging from 81.8–93.8% [11, 15, 16]. One of the reasons why the effective rate varied in these reports was that the proportion of previous surgical procedures for participators vary. Different types of previous surgical procedures may have had different effects on the treatment of PBC for recurrent TN. Xu et al. reported that the efficacy of PBC for patients with recurrent TN after MVD was 92.9% [9]. Our results demonstrate that, after MVD alone, the effective rate of patients receiving PBC was 90.9%, which was consistent with Xu et al.'s study [9]. Unlike Chen et al.'s report, in which the effective rate of PBC after MVD was only 81% [4]. We also found that, after repeated PBC alone, only 7 patients (77.8%) who had undergone previous PBC experience d pain relief within one month. And the efficacy of the present study was inferior to Chen et al.'s report (30, 93.8%) [10]. Of course, the number of patients who underwent repeated PBC in this study was only 9, so our results need to be further confirmed. In the present study, failure of puncture during PBC procedure or procedures with atypical pear balloon shape were excluded. Hence, we suspect a higher failure rate of PBC in patients whose therapeutic target is the semilunar ganglion for recurrent TN after TN-related surgeries; which may also be related to the once damaged local structure of semilunar ganglion during previous surgical procedures [10]. Unfortunately, the specific mechanism of lower analgesic efficacy of PBC for recurrent TN following surgical procedures was uncertain to date, which needs to be further confirmed by conducting animal experiments.

Although a sizable body of studies demonstrated the importance of objective clinical predictors of curative effect, the selection of recurrent TN patients undergoing previous surgeries for PBC was still subjective [20]. To our knowledge, there were fewer objective scale established for the prediction of recurrent TN patients following PBC. Therefore, this is the first study of its kind with a relatively large numbers of cases to propose predictive factors of PBC therapeutic efficacy for recurrent TN. In our study, among preoperative data such as, age, gender, BMI, comorbidities, duration of disease, time to recurrence, baseline NRS score, carbamazepine dose pre-PBC, affected side of TN, distribution of pain, history of previous surgeries, BNI facial hypesthesia scale after the last surgery, we found that only previous RFT was an independent predictor of lower analgesic efficacy. Other previous surgeries such as MVD, PBC, GKRS and GR did not affect the analgesic efficacy of PBC. It is generally known that the rationale of RFT on TN is to destroy Aα and Aβ fibers, thus to interrupt the peripheral stimuli and reach the central nervous system [21]. It is not clear why the curative effect of PBC after RFT would be limited. We speculate that, RFT may form scar tissue in the semilunar ganglion, which maybe the reason for lower analgesic efficacy of PBC. In the ineffective group of our study, six out of 20 patients with recurrent TN following previous RFT underwent repeated RFT for further nerve destruction and all of them achieved good pain relief. Consequently, we can speculate that repeated RFT may be suitable for patients with recurrent TN after RFT. Several previous studies showed that, in addition to the shape of the balloon, the volume as well as the duration of compression may be related to PBC outcome [22]. It can be speculated that regular

compression time and balloon volume may not be suitable for recurrent TN patients with previous history of RFT. Perhaps increasing the volume of the balloon and prolonging compression time may improve pain relief rate. As a result, optimal PBC compression time and balloon volume for patients who had a history of previous RFT needs to be investigated in future studies. Similarly, Liu et al. reported that, patients who underwent repeated RFT and achieved an "excellent" or "good" pain relief condition (VAS score ≤ 1) were 96.8% at 6 months and 83.9% at 1 year [23]. Therefore, we speculate that, in patients with recurrent TN after RFT, repeated RFT might be a useful treatment option. Certainly, prospective, randomized, controlled clinical trials need to be conducted, for optimization of treatment module in recurrent TN patients following previous failed surgical interventions.

Regarding complications, facial numbness is the most common side effect after PBC, but it is relatively mild and closely related to the treatment mechanism and PBC operation. According to previous reports, the incidence rates of postoperative facial numbness ranged from 89%-100% [9, 13, 24]. In our study, 91.5% presented with facial numbness in the effective group, which was much higher than those in the ineffective group (P = 0.00). This shows that the patients who had facial numbness had a greater likelihood of being pain free. Participants who had complete pain relief had worse or new trigeminal numbness [10]. Masseter weakness was also reported to be a common complication after PBC. In our study, 34.6% patients developed masseter weakness in the effective group, which was higher than that in the ineffective group (10%, P = 0.04). The complications were similar to those reported by Xu et al. [9], which were higher than previous studies [10, 24]. Diplopia after PBC was reported previously by Bergenheim and Linderoth [25]. Although in our study, 4.6% patients developed diplopia in the effective group compared to 5.0% in the ineffective group, it was most often transient, and had resolved within 3 months. Furthermore, no serious side effects were observed in our study, which is in line with current opinion that these procedures are generally safer with image guidance.

Limitation

This study has several limitations. First, this is a retrospective study and the retrospective nature of this study creates inherent bias. So a prospective validation of the prognostic tool is still needed. Second, intraoperative parameters of RFT may affect the effectiveness of PBC, however, we were unable to obtain those parameters such as treatment location, temperature, operation time and so on. Third, due to the lack of specific detailed intraoperative records, our study did not differentiate MVD with PSR. Fourth, the follow-up period was relatively short. Long-term effects of PBC on recurrent TN need a longer patient follow-up period. The good news is that all of these patients will be continuously monitored, and further reports could give an even clear picture of PBC on recurring TN.

Conclusion

In this study, PBC was found to be a moderately effective and safe treatment for recurrent TN after TN-related surgery. However, previous RFT procedure may predict a slightly worse outcome after PBC and should be considered in clinical decision making.

Declarations

Ethical approval and Consent to participate All procedures performed were in accordance with the ethical standards. Our study was approved by the Medical Ethics Committee of Beijing Tiantan Hospital, Capital Medical University. All experiments were performed in accordance with relevant named guidelines and regulations. The study is exempt from the requirement for informed consent.

Human and animal ethics This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Beijing Tiantan Hospital, Capital Medical University. Research involved human participants, their data and vital signs.

Consent for publication All authors consent to the submission of the manuscript in Neurosurgical Review. All authors guarantee that the research findings have not been previously published.

Availability of supporting data Patient data will not be available because this was not a concern when the study was conducted and the patients were not informed.

Competing interests The authors declare that they have no competing interests.

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Authors' contributions FL were responsible for the study design. FL conceived the idea for this study. Study conduction and data collection was led by LL, ZS, YZ and GF M. Study analysis and figure generation was done by LL, supervised by FL. LL and ZS wrote the main manuscript text and YZ and GF M prepared figures 1. LL and ZS contributed equally to this work and should be considered co-first authors. All authors reviewed the manuscript.

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Tables

Table 1
Demographic data and clinical Characteristics of Patients

	Effective Group	Ineffective Group	T/Z/ χ^2	P
Number, No.(%)	130(86.7%)	20(13.3%)		
Age, median (range) (y)	66(36, 87)	66(48, 83)	-0.07	0.95
Gender, No. (%)				
Male	56(43.1%)	6(30%)	1.22	0.27
Female	74(56.9%)	14(70%)		
BMI, mean ± SD, kg/m^2	23.2 ± 3.2	22.1 ± 2.5	1.07	0.30
Comorbidities, No.(%)				
Hypertention, No.(%)	19(14.6%)	3(15.0%)	0.00	0.96
Heart diseases, No.(%)	4(3.1%)	2(10.0%)	0.74	0.39
Stroke, No.(%)	5(3.8%)	1(5.0%)	0.14	0.71
Duration of disease, median (range) (y)	7(2,40)	8(2,23)	-0.40	0.69
Time to recurrence, median (range) (y)	2(0, 20)	1.15(0, 36)	-0.32	0.75
Baseline NRS score, median (range)	7(6, 8)	7(7, 8)	-0.71	0.48
Carbamazepine dose pre-PBC, median (range) (mg/day)	600 (200, 1800)	600 (200, 900)	-0.23	0.82
Affected side of TN, No.(%)				
Left	51(39.2%)	11(55%)	1.78	0.18
Right	79(60.8%)	9(45%)		
Distribution of pain, No.(%)			3.79	0.58
V1	1(0.8%)	1(5.0%)		
V2	15(11.5%)	2(10.0%)		

Data are expressed as mean ± standard deviation, or median (range), number (%). χ2, chi-square test. *BMI*, body mass index; *TN*: trigeminal neuralgia; *NRS*, numeric rating scale; *MVD*, microvascular decompression; *PSR*, partial sensory rhizotomy; *RFT*, radiofrequency thermocoagulation; *PBC*, percutaneous balloon compression; *GKRS*, gamma knife radiosurgery; *GR*, glycerol rhizotomy; V1 = Ophthalmic division; V2 = maxillary division; V3 = mandibular division. *BNI*, Barrow Neurological Institute; The degree of ipsilateral facial numbness was assessed by the BNI facial hypesthesia scale: Class I: no facial numbness; Class II: mild facial numbness and not bothersome; Class III: facial numbness and somewhat bothersome; Class IV: facial numbness and very bothersome.

	Effective Group	Ineffective Group	T/Z/ χ^2	P
V3	21(16.2%)	4(20.0%)		
V1 + V2	8(6.2%)	2(10.0%)		
V2 + V3	69(53.1%)	9(45.0%)		
V1 + V2 + V3	16(12.3%)	2(10.0%)		
History of previous surgeries for TN, No.(%)				
Previous MVD alone	70 (53.8%)	7 (35%)	2.46	0.12
Previous RFT alone	14(10.8%)	6 (30%)	5.55	0.02
Previous GKRS alone	13(10.0%)	1(5%)	0.59	0.69
Previous GR alone	10(7.7%)	2(10%)	0.12	0.66
Previous surgeries for TN ≥ 2	16 (12.3%)	2(10%)	0.01	0.94
BNI facial hypesthesia scale after the last surgery, No.(%)			2.60	0.27
Class I	110(84.6%)	14(70.0%)		
Class II	17(13.1%)	5(25.0%)		
Class III	3(2.3%)	1(5%)		

Data are expressed as mean ± standard deviation, or median (range), number (%). χ2, chi-square test. *BMI*, body mass index; *TN*: trigeminal neuralgia; *NRS*, numeric rating scale; *MVD*, microvascular decompression; *PSR*, partial sensory rhizotomy; *RFT*, radiofrequency thermocoagulation; *PBC*, percutaneous balloon compression; *GKRS*, gamma knife radiosurgery; *GR*, glycerol rhizotomy; V1 = Ophthalmic division; V2 = maxillary division; V3 = mandibular division. *BNI*, Barrow Neurological Institute; The degree of ipsilateral facial numbness was assessed by the BNI facial hypesthesia scale: Class I: no facial numbness; Class II: mild facial numbness and not bothersome; Class III: facial numbness and somewhat bothersome; Class IV: facial numbness and very bothersome.

Table 2
Operation Variables, Efficacy and Complications

	Effective Group	Ineffective Group	T/Z/ χ^2	P
Number, No. (%)	130(86.7%)	20(13.3%)		
Trigeminal cardiac reflex during operation, No. (%)	48(36.9%)	9(45.0%)	0.48	0.49
Operation duration, mean ± SD (min)	24 ± 6	25 ± 4	-0.72	0.47
Balloon volume, mean ± SD (ml)	0.61 ± 0.12	0.58 ± 0.09	1.07	0.29
Compression time, mean ± SD (s)	101 ± 14	97 ± 15	1.18	0.24
The NRS score immediate after PBC, median (range)	2(0, 4)	7(6, 8)	-7.38	0.00
Complications, No. (%)				
Herpes simplex, No. (%)	17(13.1%)	1(5.0%)	0.44	0.51
Masseter weakness, No. (%)	45(34.6%)	2(10.0%)	4.85	0.04
Facial numbness, No. (%)	119(91.5%)	4(20.0%)	60.1	0.00
Diplopia, No. (%)	6(4.6%)	1(5.0%)	0.24	0.62

Data are expressed as mean ± standard deviation, or median (range), number (%). χ^2, chi-square test. *NRS*, numeric rating scale.

Table 3
Univariate analysis for recurrent TN outcome after PBC

Variable	Patients, No.	OR	95% CI	*P*
Number	150			
Age(y)		0.78	0.29–2.03	0.61
≤ median age (66-y-old)	82			
> median age (66-y-old)	68			
Gender		1.77	0.64–4.88	0.27
Male	62			
Female	88			
BMI		0.61	0.23–1.59	0.31
≤ median BMI (22.8kg/m^2)	74			
> median BMI (22.8kg/m^2)	76			
Comorbidities				
Hypertention	22	0.97	0.26–3.63	0.96
Diabetes mellitus	10	1.41	0.17–11.80	0.75
Heart diseases	6	0.29	0.05–1.67	0.17
Stroke	6	0.76	0.08–6.86	0.81
Duration of disease		0.96	0.37–2.46	0.92
≤ median duration (7-y-old)	81			
> median duration (7-y-old)	69			
Time to recurrence		1.34	0.52–3.45	0.54
≤ median time (2 years)	73			
> median time (2 years)	77			
Baseline NRS score		0.91	0.35–2.38	0.84
Moderate (≤ 7)	93			

OR, odds ratio, *CI*: Confidence Interval; *BMI*, body mass index; *TN*: trigeminal neuralgia; *NRS*, numeric rating scale; *MVD*, microvascular decompression; *PSR*, partial sensory rhizotomy; *RFT*, radiofrequency thermocoagulation; *PBC*, percutaneous balloon compression; *GKRS*, gamma knife radiosurgery; *GR*, glycerol rhizotomy; V1 = Ophthalmic division; V2 = maxillary division; V3 = mandibular division. *BNI facial hypesthesia scale*: No facial numbness: Class I; facial numbness: Class II or above: facial numbness and some bothersome.

Variable	Patients, No.	OR	95% CI	*P*
Severe (> 7)	57			
Carbamazepine dose pre-PBC		0.67	0.16–2.79	0.59
≤ 600	101			
> 600	49			
Affected side of TN		0.53	0.21–1.36	0.19
Left	88			
Right	62			
Distribution of pain				0.88
V1	2			
V2	17	0.17	0.01–3.89	0.27
V3	25	0.18	0.01–3.66	0.26
V1 + V2	10	0.17	0.01–5.45	0.31
V2 + V3	78	0.14	0.01–2.52	0.18
V1 + V2 + V3	18	0.15	0.01–3.58	0.24
History of previous surgeries for TN				
Previous MVD alone	77	2.17	0.81–5.78	0.12
Previous PBC alone	9	0.51	0.01–2.66	0.43
Previous RFT alone	20	0.28	0.09–0.85	0.03
Previous GR alone	12	0.75	0.15–3.70	0.72
Previous surgeries for TN ≥ 2	18	1.26	0.27–5.96	0.77
BNI facial hypesthesia scale after the last surgery		2.51	0.90–6.97	0.08
Class I (No)	120			
Class II or above (Yes)	30			

OR, odds ratio, *CI*: Confidence Interval; *BMI*, body mass index; *TN*: trigeminal neuralgia; *NRS*, numeric rating scale; *MVD*, microvascular decompression; *PSR*, partial sensory rhizotomy; *RFT*, radiofrequency thermocoagulation; *PBC*, percutaneous balloon compression; *GKRS*, gamma knife radiosurgery; *GR*, glycerol rhizotomy; V1 = Ophthalmic division; V2 = maxillary division; V3 = mandibular division. *BNI facial hypesthesia scale*: No facial numbness: Class I; facial numbness: Class II or above: facial numbness and some bothersome.

Table 4
Relationship between preoperative variables and recurrent TN outcome after PBC in different models

Variables	Non-adjusted (OR, 95%CI, P)	Adjust I (OR, 95%CI, P)	Adjust II (OR, 95%CI, P)
previous RFT			
No	Reference	Reference	Reference
Yes	0.28 (0.09–0.85), 0.03	0.28 (0.09–0.85), 0.02	0.30 (0.09–0.96), 0.04

OR, odds ratio, *CI*: Confidence Interval; Non-adjusted model adjust for: none. Adjust I model adjust for: gender and age. Adjust II model adjust for: age, gender, BMI, comorbidities, duration of disease, time to recurrence, baseline NRS score, carbamazepine dose pre-PBC, affected side of TN, distribution of pain, BNI facial hypesthesia scale after the last surgery.

Figures

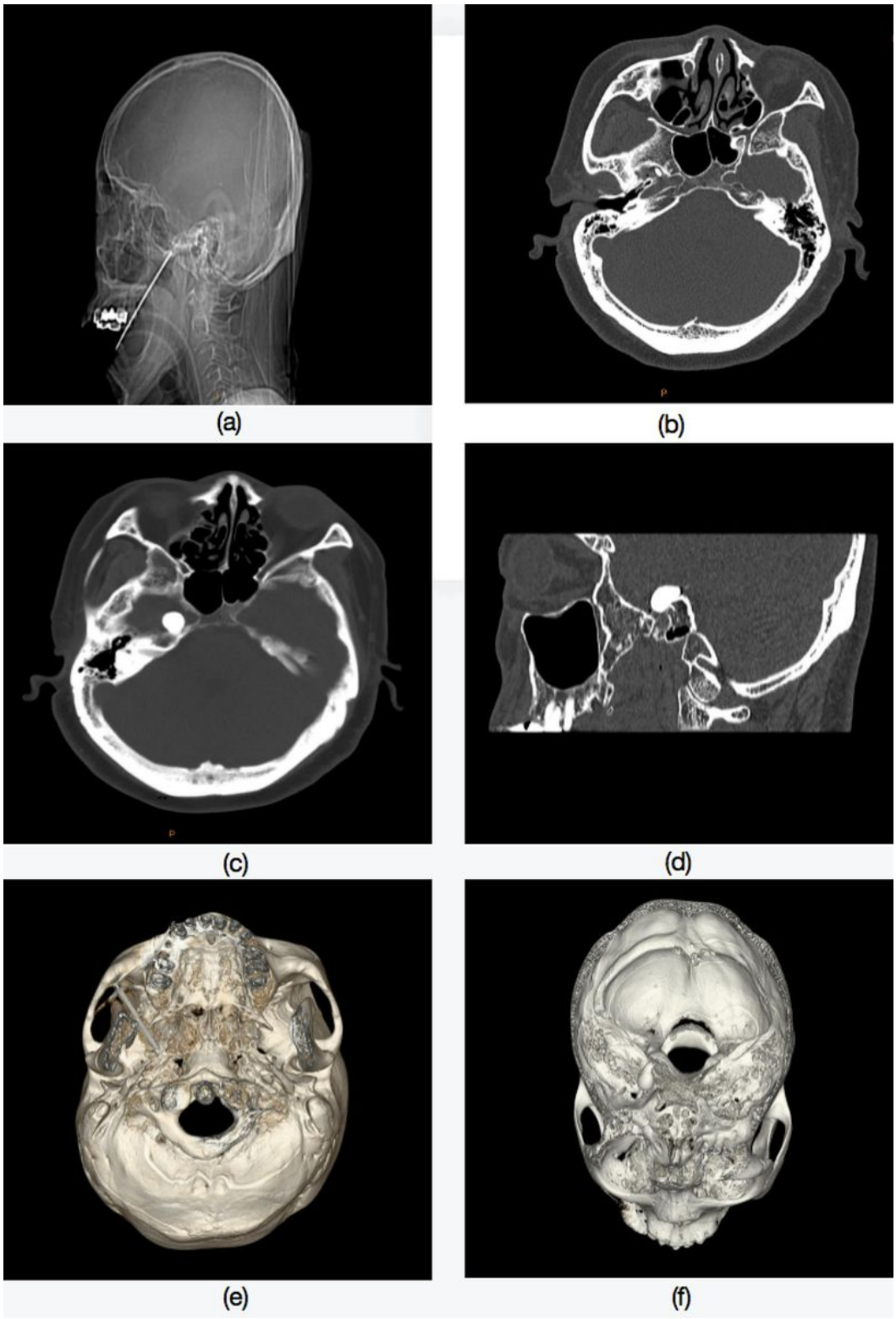

Figure 1

2D images and reconstructed 3D-CT images during percutaneous balloon compression. The cannula entered the foramen ovale was shown in sagittal (a) and axial (b) planes. The pear-shaped balloon was viewed in axial(c), sagittal(d) planes. Reconstructed 3D-CT images provided confirmation of the position and shape of the balloon(e,f).