Research Article

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Percutaneous radiofrequency trigeminal rhizotomy for the treatment of idiopathic trigeminal neuralgia: Experience in 106 patients

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Abstract

Objective: The aim of our study is to analyse the results of percutaneous radiofrequency trigeminal rhizotomy for treatment of idiopathic trigeminal neuralgia.

Methods: We inspected the results of 106 patients with the diagnoses of idiopathic neuralgia that treated with percutaneous radiofrequency trigeminal rhizotomy retrospectively. The scores of visual analog scale(VAS) were noted preoperative and postoperative periods at 1st, 3rd, 6th and 12th months and were used for statistical analysis.

Results: Mean age of 106 patients was 67.31±8.85 years. Duration of symptoms was 19.1±13.1 months. Duration of symptoms did not change significantly according to gender (p=0.755), or site of trigeminal pain (p=0.158). There was not any statistical significance between gender, effected branch of trigemial nerve and side of the pain. Preoperative mean VAS score was 9.6±0.75. Postoperative mean VAS score values were 3.25±2.44 at first month, 3.23±2.43 at third months, 3.12±2.78 at sixth months and 2.59±3.18 at postoperative twelfth months. We found statistically significant difference between preoperative and postoperative 1st, 3rd, 6th and 12th months VAS scores (p<0.001).

Conclusion: Percutaneous radiofrequency trigeminal rhizotomy is the minimally invasive treatment modality with lower complication rates and it has a high rate of efficacy when compared with invasive methods. It is most cost-effective procedure to choose if the pain recurs.

Keywords: Radiofrequency, rhizotomy, trigeminal neurologia

INTRODUCTION

Trigeminal neuralgia (TN) is defined as "sudden, usually unilateral, severe, brief, stabbing, recurrent episodes of pain in the distribution of one or more branches of the fifth cranial nerve" by The International Association for the Study of Pain (1, 2). The incidence of TN is 3 to 27 persons per 100,000 population in the literatures whereas the incidence of idiopathic trigeminal neuralgia (ITN) is reported as 4-5 patients per 100,000 population (3, 4). This type of neuralgia mainly affects especially women at the middle-ages and olders. It is unilaterally affected at onset encountered (5). The symptoms of TN with severe pain is described as excruciating and poses serious impairment quality of life (6). Patient who had more and severe episodes complains the symptoms like conjunctival hyperemia, lacrimation, salivation, facial redness, tilted mouth to one side, and reflexive facial tic (7). Despite the efforts of pharmacological researches on TN; medical management fails in most cases.

Many treatment modalities were suggested for TN that include medical and surgical options. The drugs available for medical treatment are carbamazepine, oxcarbazepine, lamotrigine, baclofen and pimozide (8). The poor drug tolerance is the main problem with medical management that is connected with many factors (9). Surgical and percutaneous treatments for TN include microvascular decompression (MVD), glycerol rhizotomy (GR), balloon compression (BC), percutaneous radiofrequency thermo-rhizotomy(PRT) and gamma-knife radiosurgery (10-14). Mentioned procedures above generally show effective pain relief that derives from directed injury to the pain fibers in the trigeminal nerve for all treatments. However, they are different on type of injury inflicted and with the selectivity of trigeminal divisions.

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To date, percutaneous treatments which are BC, GR and PRT have been accepted for the treatment of TN patients who had ressistance to medication. We reported the results of our patients who were treated with PRT of the trigeminal Gasserian ganglion, as more effective and minimally invasive treatment modality.

METHODS

One hundred and six patients with ITN were treated with PRT between 2007 and 2013 at Department of Algology. This is a retrospective study which is adequate with Helsinki Declations that reported from patients files. Written informed consent was obtained from patients who participated in this study. All of the 106 cases had unilateral ITN and they were using single medicine which was recommended by several disciplines before presenting to our clinic. These medicines were carbamazepine, gabapentin and pregabalin. The diagnosis was made by anamnesis, definition of paroxysmal pain as electric shock-like. Patients have no pathologies on magnetic resonance imaging (MRI) of cranium and no benefit from medical therapy. The exclusion criterias for selection of the patients were pathological neurological findings related to the trigeminal nerve, any involvement of artery, vein or intracranial mass reported with cranial MRI, local infection at procedure site or systemic infection, uncontrollable hypertension, coagulopathy, major depression and pyschotic disorders. All selected patients had unilateral ITN, PRT was applied only once and medical treatment were stopped immediately after the procedure. Visual Analog Scale (VAS) scores were evaluated at the time of procedure and postoperative 1st, 3rd, 6th and 12th months.

Surgical Protocol

Patient was prepared with supine position on the X-ray compatible table. Head and shoulders were positioned on a headboard with the head extension over the end of the table. The continuous monitoring of pulse oxygen saturation, electrocardiography and noninvasive blood pressure were prepared. About 3 L/min oxygen was given through a nasal airway. During the procedure anesthesia was given with intravenous injection of 0.03- 0.05mg/kg midazolam depending the age of the patient.

The optimal view of the foramen ovale is obtained on the side of the lesion with a C-arm fluoroscope by 20° extension up and 15-20° rotation far away from the pain localization. About 1% lidocaine was used for the local anesthesia and 22-G disposable straight electrode with a 2-mm active end (NeuroTherm®, Radionics, Burlington, MA, USA) was inserted with stylet to the localization 2.5 cm away from mouth angle with the perioral approach. When the optimal position has been obtained the stylet was then removed. Mostly there is a cerebrospinal fluid free-flow which is the landmark to confirm the localization of the needle placed inside foramen ovale. After the end of the electrode had been placed appropriately in the Gasserian ganglion, the final location was decided by the patient's response to the electrical stimulation between 0.1 to 1.5 V at 50-100 Hz. If the satisfactory localization of electrode end has been decided, PRT procedure was applied with the temperature of 70°C for 60 seconds (Neurotherm Radio Frequency Lesion Generator Service Manual Model NT1100).

The patient was asked and examined for sensation of the sides of the face and bilateral corneal reflexes were checked and compared. If there was no effective pain relief, the PRF was repeated until the effective pain relief was achieved. Usually the patient stays in hospital for 1 day to follow for any complications that could occur. Medication with antibiotics were administered for five days but medications for ITN were completely stopped after procedure.

Statistical Analysis

The chi-square statistic was used to show whether or not there was a relationship between two categorical variables. The Kolmogorov-Smirnov test was used to compare the cumulative distributions of two data sets. The comparison of three or more samples was made with nonparametric Kruskal-Wallis test. The comparison of two unpaired groups were made with the Mann-Whitney test. The Mann-Whitney test was also used for post-hoc comparisons after Kruskall-Wallis test. The association between two ranked variables is tested with the Spearman rank correlation. In this probability of committing a Type I error was 5%. IBM SPSS Statistics V21.0 (IBM Corp.; Armonk, NY, USA) was used for statistical analysis.

Follow-up

Follow up periods were 1 month, 3 months, 6 months and 1 year after the procedure for all patients. They were examined for dysesthesia, facial hypoalgesia and questioned for side effects and any complications. VAS scores were collected each time.

RESULTS

All patients were managed with a single PRF procedure. Fifty-nine (55.7%) patients were woman and 47 (44.3%) were man. Mean age of patients was 67.31± 8.85 years. Age, length and weight of the patients were shown at Table 1. Duration of symptoms was 19.1±13.1 months. Duration of symptoms did not change significantly according to gender (p=0.755), or site of trigeminal pain (p=0.158) (Table 2). The relation of effected branch of trigeminal nerve to gender and site of trigeminal pain was shown in Table 3. There was no relation between affected branch of trigemial nerve and gender and site of the pain.

Immediately after the procedure, 42 patients have had different degrees of facial numbness. This facial numbness disappeared after 7 days. Regarding these 42 patients, 38 of them had pain relief after the procedure, however in four patients there was facial numbness and no pain relief. One patient had

Table 1. Age, length and weight of the patients with trigeminal neuralgia

	All group		Male		Female		Statistical difference
	Mean	SD	Mean	SD	Mean	SD	p
Age (year)	67.31	8.85	68.49	8.60	66.37	9.00	0.223
Length (cm)	165.92	8.11	170.74	7.14	162.08	6.70	<0.001
Weight (kg)	78.36	8.90	83.04	7.61	74.63	8.10	<0.001

SD: standard deviation; cm: centimeter; kg: kilograms

Table 2. Duration of trigeminal pain according to gender and site of the pain

	All group		Male		Female		Statistical difference	Right side		Left side		Statistical difference
	Mean	SD	Mean	SD	Mean	SD	p	Mean	SD	Mean	SD	p
Duration (month)	19.1	13.1	20.5	15.0	17.9	11.3	0.755	17.6	13.0	20.5	13.1	0.158

SD: standard deviation

Table 3. Trigeminal nerve branches according to side of the pain and age of the patient

		All group		Right side		Left side		Statistical difference	Male		Female		Statistical difference
		n	%	n	%	n	%	p	n	%	n	%	p
Ophthalmic	(-)	83	78.3	45	83.3	38	73.1	0.242	39	83.0	44	74.6	0.349
	(+)	23	21.7	9	16.7	14	26.9		8	17.0	15	25.4	
Maxillary	(-)	43	40.6	28	51.9	15	28.8	0.019	18	38.3	25	42.4	0.695
	(+)	63	59.4	26	48.1	37	71.2		29	61.7	34	57.6	
Mandibular	(-)	36	34.0	17	31.5	19	36.5	0.683	16	34.0	20	33.9	0.988
	(+)	70	66.0	37	68.5	33	63.5		31	66.0	39	66.1	

n: number of patients

Table 4. VAS score changes after percutaneous radiofrequency rhizotomy

	VAS (start)		VAS (1 month)		VAS (3 month)		VAS (6 month)		VAS (12 month)		Statistical difference
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	p
VAS	9.60	0.75	3.25	2.44	2.23	2.43	2.12	2.78	2.59	3.18	<0.001

SD: standard deviation; VAS: visual analog scale

causalgia, 3 patients had pain at needle insertion site and 2 patients had ecchymosis which recovered in ten days at needle insertion site.

Preoperative and postoperative 1st, 3rd, 6th and 12th months VAS scores were compared. Preoperative mean VAS score was 9.6±0.75. Postoperative mean VAS score values were 3.25±2.44 at first month, 3.23±2.43 at third months, 3.12±2.78 at sixth months and 2.59±3.18 at postoperative twelfth months. Statistically significant difference was found between preoperative and postoperative first, third, sixth, and twelfth months VAS scores (p<0.001). VAS scores were presented in Table 4.

DISCUSSION

Trigeminal neuralgia is diagnosed by paroxysmal ancinating and very severe facial pain in the territory of the 5th cranial nerve (15). TN is the most common type of cranial neuralgia (16). Even it is usually seen unilaterally, systemic diseases must

be remembered when it is seen bilaterally (17). Involvement of second and third branches are more encountered than first branch of trigeminal nerve (18-20). Diagnosis of TN could be made by anamnesis and definition of pain (16). MRI could separate secondary TN from ITN. The pathopysiology of pain with TN remains still controversial. The probable pathogenic process was reported that pulsatile or sustained microvascular compression causes demyelination on sensory axons in the trigeminal root by Dandy (21). Rappaport and Devor reported ignition hypothesis that trigeminal microcompression renders trigeminal afferent neurons, both axotomized somata and injured axons, hyperexcitable (22). The hyperexcitable afferents induce pain paroxysms as a result of synchronized after discharge activity that originates at ectopic pacemaker sites of trigeminal ganglion or in the root. The quality of life of TN patients were affected significantly because the ignition factors including washing of the face and going out in cold wind, shaving, applying of make-up, teeth brushing, vibrations from walking can evoke paroxysmal pain (6, 16). Depression, anxiety and sleep disturbance are pain-related comorbidities that have a significant effect on quality of life (22).

First historical description about TN belong to Cappadocian Aretaeus at A.D. 2nd century according to Stookey and Ransohoffs' research (23). Rethiwith who tried to electrocoagulate the Gasserian ganglion rootlets and trigeminal nerve first developed the radiofrequency lesioning in 1913 (9). White and Sweet had showed procedure to be effective for pain relief in 1975 (24, 25). Then Tew and van Loveren pioneered the use of thermocoagulation (26, 27).

Up to date two types of radiofrequency thermocoagulation system have been mostly in use. Conventional radiofrequency thermocoagulation is a clinically effective treatment for reducing neuropathic pain. It produces 45°C or more of temperature with a constant output of high-frequency electric current, resulting in neuroablative thermocoagulation (28). Pulsed radiofrequency thermocoagulation, supports short "pulses" of high-voltage, radiofrequency range electric current to maintain the same voltage fluctuations in the localization of treatment which occur during conventional radiofrequency thermocoagulation treatment, but not to a degree that causes tissue coagulation (28). The heat supported is instead dissipated between the pulses. Pulsed radiofrequency can reduce the risk of nerve injury by providing pulses of high frequency current with heat dissipation between pulses. Pulsed radiofrequency is not preferred for an effective procedure of pain treatment modality for TN (19). We use conventional PRF at our patients. The exact mechanism of PRT on TN treatment could not be explained clearly. One of the potential mechanisms of pain relief using PRT technique is the differential thermocoagulation of the trigeminal rootlets which proposes that the action potentials of nosiceptive fibers (A-delta and C) are blocked at lower temperatures than those that transmit tactile sensation (4). Another mechanism is hypothesized as reducing the recruitment of ectopic neural activity.

There is a huge variety of treatment modalities as pharmacological and surgical for TN. After the invention of phenytoin at 1942, anticonvulsant medicines became the first choice of treatment for TN. Carbamazepine have been the gold standard medical therapy. The first step has medical therapy of the drugs available are oxcarbazepine and carbamazepine. The second step is lamotrigine, pimozide and baclofen. Clonazepam, levetiracetam, phenytoin, gabapentin, valproate, topiramate and tocainide could be also given. Poor drug tolerance is the main problem with medical management that related to many reasons (9).

Unluckely, nobody could describe a method or medication for the complete relief of the intolerable pain without recurrence of TN. Radiofrequency of the semilunar ganglion, peripheral branch rhizotomy, semilunar ganglion sacculus proprius compression, avulsion, retrogasserianectomy or carding manipulation, retrogasserian glycerol ectomy, MVD and gamma knife surgery are the surgical treatment modalities of TN (29, 30). Correction of the hypothesized vascular etiology could be only made with MVD by repositioning the vessel (31). This technique not only have the lowest rate of pain recurrence but also supplies the highest rate of long-term patient's satisfaction (12). MVD is the only treatment that can cure TN pain without coagulating or destroying the trigeminal nerve whereas it has a high recurrence rate and unsuccessful patient population (12, 31, 32). Four thousand, eight hundred and eighty-four patients were reported by Tatli with MVD procedure and found the initial pain relief, follow-up pain free and recurrence rates of the MVD patients range between 76.4–98.2%, 62–89% and 4–38% (33, 34).

Percutaneous treatment modalities are chosen for the patients who are resistant to medical therapy, do not want any invasive methods and older than 50 years of age (15). When compared with different operative percutaneous procedures for TN, PRT have some advantages over the other techniques. Recurrence rates of PRT are lower than the rates of GR (35). PRT is more selective and isolated division treatment than BC. Furthermore PRT has proven to be more effective and safer treatment with the diagnosis of TN with multiple sclerosis that have higher recurrence rates or treatment failure (17, 36). Sivahanthan et. al. investigated the most cost-effective treatment modality for the treatment of TN and they reported PRT as the best one according to their criterias (37).

Kanpolat et al. had a huge PRT series that consisted of 1600 patients and stated that complete pain relief was reported to be achieved at five years in 57.7% of the patients that applied a single procedure and overall recurrence rate was found to be 25.1% (3). Tang et al. reported 272 patients treated with PRT at computed tomography guidance and satisfactory rate was 100% after the procedure but the reccurence rate was 25% at 14 years follow-up (38, 39). Teixeira et al. inspected 272 patients after PRT procedure and pain relief after procedure

rate was 100% with a 44% reccurence at one year follow-up (2). There are smaller written series in the literature which are reported by Taha et al., Balevi et al., Nie et al., Singh et al. and Son et al. Their pain relief rates are between 77-100% after procedure and reccurence rates are between 20-40% (7, 9, 40, 41). We have 96,2% pain relief immediately after the procedure in 106 patients and 4 patients had undergone a second procedure for recurrence in our series.

Park et al. categorized the satisfaction rate for the management of the pain after PRT into five categories: excellent, good, poor, failure, and recurrence (42). Borrow Institute also made a pain scale to classify the outcome of TN procedures (4, 16, 29). In our study, we used VAS score at preoperative and postoperative 1st, 3rd, 6th and 12th months to follow success of the procedure.

Although pioneering developments of percutaneous procedures, variety of complications still remain with low incidence. These complications can be countered as corneal hypoesthesia, corneal anesthesia, corneal - palpebral reflex deficit, keratitis, corneal ulcer, paresthesia, anesthesia dolorosa, anesthesia of trigeminal branches, herpes simplex infection, numbness sensation, dysesthesia, motor masseteric deficit, paralysis of ocular nerves (2, 8, 43). Dysesthesias are usually associated to more intense sensory deficit. It is probable that higher sensory deficit is an indication of higher success rate (43). Severe complications like intracranial haemorrhage, meningitis, carotid injuries, carotid-cavernous fistulae are rare (44, 45). The severity and number of the lesions could be arranged according to the degree of resulting hypoalgesia, mandibular deviation and the ciliary reflex changes after each lesion. In our study 42 patients had different degrees of facial numbness, 1 patient had causalgia, 3 patients had pain at needle insertion site and 2 patients had ecchymosis at needle insertion site as reported complications which resolved after at least 10 days. The well-known complications of PRF for the treament of TN in the first division, such as loss of ciliary reflex and keratitis, were absent in our series.

Percutaneous radiofrequency thermo-rhizotomy must be remembered as a primary percutaneous treatment on selected patients whom medical therapy is ineffective and can not be candidates for surgery. Percutaneous radiofrequency trigeminal rhizotomy is the minimally invasive treatment modality with lower complication rates and it has a high rate of efficiancy when compared with invasive methods. It is most cost-effective procedure to choose if the pain recurs.

Ethics Committee Approval: Authors declared that the research was conducted according to the principles of the World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects" (amended in October 2013).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

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REFERENCES

1. Headache Classification Subcommittee of the International Headache Society. The International Classification of Headache Disorders. Cephalalgia 2004; 24: 9–160.
2. Teixeira MJ, Siqueira SRDT, Almeida GM. Percutaneous radiofrequency rhizotomy and neurovascular decompression of the trigeminal nerve for the treatment of facial pain. Arq Neuropsiquiatr 2206; 64: 983-989. [CrossRef]
3. Kanpolat Y, Berk C, Savas A, Bekar A. Percutaneous controlled radiofrequency rhizotomy in the management of patients with trigeminal neuralgia due to multiple sclerosis. Acta Neurochir (Wien) 2000; 142: 685-689. [CrossRef]
4. Missios S, Mohammadi AM, Barnett GH. Percutaneous treatments for trigeminal neuralgia. Neurosurg Clin N Am 2014; 25: 751-762. [CrossRef]
5. Zhang LW, Liu YG, Wu CY, Xu SJ, Zhu SG. Radiofrequency thermocoagulation rhizotomy for recurrent trigeminal neuralgia after microvascular decompression. Chin Med J (Engl) 2011; 124: 3726-3730.
6. Tolle T, Dukes E, Sadosky A. Patient burden of trigeminal neuralgia: results from a cross-sectional survey of health state impairment and treatment patterns in six European countries. Pain Pract 2006; 6: 153-160. [CrossRef]
7. Nie F, Su D, Shi Y, Chen J, et al. A prospective study of X-ray imaging combined with skin stimulation potential-guided percutaneous radiofrequency thermocoagulation of the Gasserian ganglion for treatment of trigeminal neuralgia. Pain Med 2014; 15: 1464-1469. [CrossRef]
8. Kanpolat Y, Ugur HC. Systematic review of ablative neurosurgical techniques for the treatment of trigeminal neuralgia. Neurosurgery 2005; 57: E601. [CrossRef]
9. Singh S, Verma R, Kumar M, Rastogi V, Bogra J. Experience with conventional radiofrequency thermorhizotomy in patients with failed medical management for trigeminal neuralgia. Korean J Pain 2014; 27: 260-265. [CrossRef]
10. Burchiel KJ, Clarke H, Haglund M. Long term efficacy of microvascular decompression in trigeminal neuralgia. J Neurosurg 1988; 68: 35-38. [CrossRef]
11. Dhople AA, Adams JR, Maggio WW, Naqvi SA, Regine WF, Kwok Y. Long-term outcomes of Gamma Knife radiosurgery for classic trigeminal neuralgia: implications of treatment and critical review of the literature. J Neurosurg 2009; 111: 351-358. [CrossRef]
12. Pamir MN, Peker S. Microvascular decompression for trigeminal neuralgia: A long-term follow-up study. Minim Invas Neurosurg 2006; 49: 342-346. [CrossRef]

13. Sindou M. Trigeminal neuralgia: a plea for microvascular decompression as the first surgical option. Anatomy should prevail. Acta Neurochir (Wien) 2010; 152: 361-364. [CrossRef]
14. Wu CY, Meng FG, Xu SJ, Liu YG, Wang HW. Selective percutaneous radiofrequency thermocoagulation in the treatment of trigeminal neuralgia: Report on 1860 cases. Chin Med J (Engl) 2004; 117: 467-470. [CrossRef]
15. Zakrzewska JM, Linskey ME. Trigeminal neuralgia. BMJ 2014; 348: g474. [CrossRef]
16. Chen HI, Lee JY. The measurement of pain in patients with trigeminal neuralgia. Clin Neurosurg 2010; 57: 129-133.
17. Kanpolat Y, Savas A, Bekar A, Berk C. Percutaneous controlled radiofrequency trigeminal rhizotomy for the treatment of idiopathic trigeminal neuralgia: 25-year experience with 1,600 patients. Neurosurgery 2001; 48: 524-532. [CrossRef]
18. Kosugi S, Shiotani M, Otsuka Y, et al. Long-Term outcomes of percutaneous radiofrequency thermocoagulation of gasserian ganglion for 2nd- and multiple-division trigeminal neuralgia. Pain Pract 2015; 15: 223-228. [CrossRef]
19. Lin B, Lu X, Zhai X, Cai Z. Use of sensory and motor action potentials to identify the position of trigeminal nerve divisions for radiofrequency thermocoagulation. J Neurosurg 2014; 121: 1497-1503. [CrossRef]
20. Sindou M. Neurophysiological navigation in the trigeminal nerve: Use of masticatory responses and facial motor responses evoked by electrical stimulation of the trigeminal rootlets for RF-thermorhizotomy guidance. Stereotact Funct Neurosurg 1999; 73: 117-121. [CrossRef]
21. Dandy WE. The treatment of trigeminal neuralgia by the cerebellar route. Ann Surg 1932; 96: 787-795. [CrossRef]
22. Weng Z, Zhou X, Liu X, Wei J, Xu Q, Yao S. Perioperative pain in patients with trigeminal neuralgia undergoing radiofrequency thermocoagulation of the Gasserian ganglion. J Craniofac Surg 2013; 24: 1298-1302. [CrossRef]
23. Stookey B, Ransoho HJ. Trigeminal neuralgia, Its story and treatment. Charles C Thomas CC, Ed. Springfield, 1959.
24. Sweet WH, Wepsic JG. Controlled thermocoagulation of trigeminal ganglion and rootlets for differential destruction of pain fibers. J Neurosurg 1974; 39: 143-156. [CrossRef]
25. White JC, Sweet WH. Pain and the neurosurgeon. A forty year experience. Charles C Thomas CC, ed. Springfield: 1969:184-197.
26. Tew JM Jr, Martens J, VanLoveren H, Taha J. Efficacy and morbidity of Linae-based stereotactic radiosurgery for the treatment of trigeminal neuralgia. In: Proeeedings of the 3rd National Trigeminal Neuralgia Conference; Oct. 26-29, p. 16, Pittsburgh; 2000.
27. vanLoveren H, Tew JM, Keller JT, Nurre MA. A 10-year experience in the treatment of trigeminal neuralgia. Comparison of percutaneous stereotaxic rhizotomy and posterior fossa exploration. J Neurosurg 1982; 57: 757-764. [CrossRef]
28. Racz GB, Ruiz-Lopez R. Radiofrequency procedures. Pain Pract 2006; 6: 146-150. [CrossRef]
29. Kim JH, Yu HY, Park SY, Lee SC, Kim YC. Pulsed and conventional radiofrequency treatment: which is effective for dental procedure-related symptomatic trigeminal neuralgia? Pain Med 2013; 14: 430-435. [CrossRef]
30. Song ZX, Qian W, Wu YQ, et al. Effect of the gamma knife treatment on the trigeminal nerve root in Chinese patients with primary trigeminal neuralgia. Turk Neurosurg 2014; 24: 163-169.
31. Sindou M, Leston J, Howeidy T, Decullier E, Chapuis F. Micro-vascular decompression for primary Trigeminal Neuralgia (typical or atypical). Long-term effectiveness on pain; prospective study with survival analysis in a consecutive series of 362 patients. Acta Neurochir (Wien) 2006; 148: 1235-1245. [CrossRef]
32. Zhang L, Zhang Y, Li C, Zhu S. Surgical treatment of primary trigeminal neuralgia: comparison of the effectiveness between MVD and MVD+PSR in a series of 210 patients. Turk Neurosurg 2012; 22: 32-38.
33. Tatli M, Satici O, Kanpolat Y, Sindou M. Various surgical modalities for trigeminal neuralgia: literature study of respective long-term outcomes. Acta Neurochir (Wien) 2008; 150: 243-255. [CrossRef]
34. Tatli M, Sindou M. Anatomoradiological landmarks for accuracy of radiofrequency thermorhizotomy in the treatment of trigeminal neuralgia. Neurosurgery 2008; 63 (Suppl 1): ONS 129-137.
35. Xu-Hui W, Chun Z, Guang-Jian S, et al. Long-term outcomes of percutaneous retrogasserian glycerol rhizotomy in 3370 patients with trigeminal neuralgia. Turk Neurosurg 2011; 21: 48-52.
36. Cheng JS, Lim DA, Chang EF, Barbaro NM. A review of percutaneous treatments for trigeminal neuralgia. Neurosurgery 2014; 10 (Suppl 1): 25-33. [CrossRef]
37. Sivakanthan S, Van Gompel JJ, Alikhani P, van Loveren H, Chen R, Agazzi S. Surgical management of trigeminal neuralgia: use and cost-effectiveness from an analysis of the Medicare Claims Database. Neurosurgery 2014; 75: 220-226. [CrossRef]
38. Tang CT, Chang SD, Tseng KY, Liu MY, Ju DT. Cyber Knife stereotactic radiosurgical rhizotomy for refractory trigeminal neuralgia. J Clin Neurosci 2011; 18: 1449-1453. [CrossRef]
39. Tang YZ, Jin D, Bian JJ, Li XY, Lai GH, Ni JX. Long-term outcome of computed tomography-guided percutaneous radiofrequency thermocoagulation for classic trigeminal neuralgia patients older than 70 years. J Craniofac Surg 2014; 25: 1292-1295. [CrossRef]
40. Son BC, Kim HS, Kim S, Yang SH, Lee SW. Percutaneous radiofrequency thermocoagulation under floroscopic image-guidance for idiopathic trigeminal neuralgia. J Korean Neurosurg Soc 2011; 50: 446-452. [CrossRef]
41. Taha JM, Tew JM Jr. Comparison of surgical treatments for trigeminal neuralgia: revaluation of radiofrequency rhizotomy. Neurosurgery 1996; 38: 865-871. [CrossRef]
42. Park SS, Lee MK, Kim JW, Jung JY, Kim IS, Ghang CG. Percutaneous balloon compression of trigeminal ganglion for the treatment of idiopathic trigeminal neuralgia : experience in 50 patients. J Korean Neurosurg Soc 2008; 43: 186-189. [CrossRef]
43. Liu C, Zhou ZG, Yuan CY. Treatment of primary trigeminal neuralgia with radiofrequency thermocoagulation: report of 648 consecutive cases. Shanghai Kou Qiang Yi Xue 2012; 21: 466-469.
44. Gokalp HZ, Kanpolat Y, Tumer B. Carotid-cavernous fistula following percutaneous trigeminal ganglion approach. Clin Neurol Neurosurg 1980; 82: 269-272. [CrossRef]
45. Chatterjee N, Chatterjee S, Roy C. Abducens nerve palsy after percutaneous radiofrequency ablation of gasserian ganglion. J Neurosurg Anesthesiol 2014; 26: 89-90. [CrossRef]