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SURGICAL MEDICAL SCIENCES / CERRAHİ TIP BİLİMLERİ

Angle and Distance Analysis on Percutaneous Trigeminal Radiofrequency Rhizotomy for Trigeminal Neuralgia

Trigeminal Nevraljide Uygulanan Perkütan Trigeminal Radyofrekans Rizotomi İşleminde Açı ve Uzaklık Ölçümlerinin Analizi

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Abstract

Objectives: Percutaneous trigeminal radiofrequency rhizotomy (RFTC) is a safe and effective intervention for trigeminal neuralgia treatment. Hartel's approach enables the surgeon to perform percutaneous foramen ovale interventions by using anatomical landmarks. We aimed to analyze the study results to verify the electrode angles and distances between the indicated anatomical landmark points.

Materials and Methods: Between 2019 and 2022, 119 out of 121 patients evaluated who underwent RFTC at the neurosurgery department. We retrospectively analyzed the electrode angles and distances radiologically and postoperative pain relief. The RFTC in our study included four parameters: the distance between petrous apex (PA) and the needle tip reaching the Gasserian ganglion in the sagittal plane, the distance between PA and the dorsum sellae in the sagittal plane,the ratio of the first parameter to the second parameter, and last measurement was the angle between PA and the dorsum sella line and the line depicting the needle pathway.

Results: There was a statistically significant difference in the PA-dorsum sellae distances between the successful and unsuccessful procedure groups ($p<0.05$). There was no statistically significant difference in the other three parameters between the two groups. The ratio of the two procedural distances was investigated to define the relation between the parameters and the success of the procedure. Receiver operating characteristic analysis was performed between PA-needle tip distance and PA-dorsum sellae distance Youden analysis of the area under the curve parameters had a cut-off value of <0.20.

Conclusion: The success of the RFTC procedure is inversely proportional with the ratio of the PA-needle tip distance to the PA-dorsum sella distance (0.20 coefficient). This ratio is an easy-to-define, reliable, and simple parameter to predict success of the intervention. Since the number of studies on the RFTC method and its radiological interpretation is limited, more cadaver and clinical studies should be performed to avoid damaging neighboring structures, increase the success rate, and determine safe penetration points and angles.

Key Words: Trigeminal Neuralgia, Percutaneous Trigeminal Radiofrequency Rhizotomy, Foramen Ovale, Trigeminal Ganglion

Öz

Amaç: Perkütan trigeminal radyofrekans rizotomi (RFTK), trigeminal nevralji için güvenli ve etkili bir müdahaledir. Hartel yaklaşımı ile cerrahın anatomik işaretler kullanarak perkütan foramen ovale müdahaleleri gerçekleştirmesi sağlanır. Bu çalışmada RFTK yapılan hastalarda elektrot açılarını ve mesafelerini radyolojik olarak ve postoperatif ağrı durumunu retrospektif olarak incelenmiştir.

Gereç ve Yöntem: Ocak 2019-Aralık 2022 tarihleri arasında nöroşirürji polikliniğinde RFTK uygulanan ve çalışmaya alınan toplam 121 hastadan 119'u çalışmaya alındı. Elektrot açılarını ve anatomik işaretler arasındaki mesafeleri analiz edilerek RFTK yapılan hastalarda dört parametre incelendi: Sagittal düzlemde petröz apeks (PA) ile Gasser ganglionuna ulaşan iğne ucu arasındaki mesafe, sagittal düzlemde PA ile dorsum sella arasındaki mesafe, ilk parametrenin ikinci parametreye oranı ve son olarak, PA ile dorsum sellae arasındaki hat ile iğne yolunun hattı arasındaki açı.

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Öz

Bulgular: Başarılı ve başarısız işlem grupları arasında PA-dorsum sella mesafelerinde istatistiksel olarak anlamlı bir fark vardı (p<0,05). Diğer üç parametrede iki grup arasında istatistiksel olarak anlamlı fark yoktu. Parametreler ve prosedürün başarısı arasındaki ilişkiyi tanımlamak için iki prosedür mesafesinin oranı araştırıldı. PA-iğne ucu mesafesi ile PA-dorsum sella mesafesi arasında alıcı işletim karakteristiği analizi yapıldı. Eğri parametreleri altındaki alanın Youden analizi <0,20'lik bir eşik değerine sahip olduğu görüldü.

Sonuç: PA-iğne ucu mesafesinin PA-dorsum sellae mesafesine oranı azaldıkça (0,20 katsayısı) RFTC prosedürünün başarısı artar. Bu oran tanımlanması kolay, güvenilir ve basit bir parametredir ve oranın girişimin başarı öngörüsüne katkısı olmaktadır. RFTK yöntemi ve radyolojik yorumu ile ilgili çalışmaların sayısı sınırlı olduğundan, komşu hayati yapılara zarar vermemek, başarı oranını yükseltmek ve güvenli penetrasyon noktalarını ve açılarını belirlemek için daha fazla kadavra ve klinik çalışma yapılmalıdır.

Anahtar Kelimeler: Trigeminal Nevralji, Perkütan Trigeminal Radyofrekans Rizotomi, Foramen Ovale, Trigeminal Gangliyon

Introduction

Trigeminal neuralgia is a type of chronic pain disorder usually characterized by unilateral and strobe pain in the sensory distribution of the trigeminal nerve. This predominantly includes the maxillary or mandibular divisions and rarely, the ophthalmic division (1). The disorder may cause recurrent, long-lasting, or near-continuous background pain over the trigeminal sensory area (2-4). As a result of this pain pattern, trigeminal neuralgia may mimic dental disorders and is often misdiagnosed. Trigeminal neuralgia symptoms, including pain and autonomic symptoms, have negative effects, disabling a patient's daily life (5,6). The disorder is classified into three categories according to its etiology (7,8). Trigeminal neuralgia without morphologic changes of the nerve root is defined as the idiopathic case, and with morphologic changes, as "classical" or "secondary" cases. In the "classical" group, the etiology is neurovascular compression, and in the "secondary" group, any disease other than neurovascular compression, such as tumors and multiple sclerosis.

Management of this disabling and difficult-to-diagnose disease consists of medical and surgical modalities. Medical options include antiepileptic drugs, topical local anesthetics, and botulinum toxin type A (4). In addition to the anamnesis and neurological examination, medical treatment is diagnostic of the disease. Patients can be medically managed only up to a certain point. Surgical options should be considered when medical treatment is unsatisfactory, and the patient's quality of life decreases due to the pain. Surgical therapies include peripheral and central procedures. Both are destructive procedures, aiming to ablate the sensory transmission pathways. Among the central surgical methods, microvascular decompression is a safe and effective option (9,10). However, because of the recurrent symptoms and surgical complications associated with this method, alternative procedures are performed (11). In case of patient-specific factors such as unwillingness to undergo surgery and older age or situations where surgery cannot be performed, percutaneous trigeminal radiofrequency rhizotomy (RFTC) is an alternative treatment option. RFTC is a safe and effective intervention for trigeminal neuralgia (12,13).

RFTC can be monitored radiologically and neurophysiologically as it is performed on a conscious but sedated patient. In addition to a radiological workup, Hartel's approach enables the surgeon to perform percutaneous foramen ovale interventions by using anatomical landmarks (14). We retrospectively analyzed the electrode angles and distances radiologically and postoperative pain relief. We aimed to analyze the study results to verify the electrode angles and distances between the indicated anatomical landmark points.

Materials and Methods

This was an observational study including a retrospective review of the digital hospital record system. The study was approved by the Ethics Committee of the Liv Hospital Ankara, Türkiye (approval number: 2022/003, decision no: 003). RFTC was performed after obtaining written consent from the patients.

Patient Population

Patients who visited the neurosurgery polyclinic for intermittent or transient facial pain and were diagnosed with trigeminal neuralgia between January 2019 and December 2022 were included in the study. The inclusion criterion was intractable pain due to trigeminal neuralgia despite efficient medical treatment. Patients were evaluated using radiological images and laboratory tests. The exclusion criteria were poor medical status, age over 90 years, abnormal neurological findings related to the trigeminal nerve, platybasia, and patients not consenting for surgery. Pain distribution was identified based on the sensory divisions of the trigeminal V1 ophthalmic, V2 maxillary, and V3 mandibular nerves. After obtaining a medical history and performing a physical examination, the followings tests were performed: electrocardiograms, chest roentgenograms, complete blood count, coagulation markers, and routine biochemical tests, including glucose, blood urea nitrogen, creatinine, sodium, potassium, albumin, aspartate aminotransferase, alanine aminotransferase, gamma-glutamyl

transpeptidase, lactate dehydrogenase, and C-reactive protein levels. The radiologic examination included magnetic resonance imaging and computed tomography for patients whose magnetic resonance imaging is contraindicated. Based on the medical history, physical examination, and biochemical and radiologic workup, patients were diagnosed and classified into trigeminal neuralgia subgroups. RFTC was performed after obtaining fitness for anesthesia. After the procedure, pain relief was assessed clinically and historically over two months. In case of ineffective intervention, RFTC was repeated.

Surgical Procedure

The procedure was performed in the operation room after obtaining verbal and written consent from the patient. The patient was placed in the supine position and sedated with intravenous midazolam (2 mg) and fentanyl (50 mcg). Atropine (0.5 mg) was administered to prevent vagal reflex-related symptoms. An entry point was identified, and an RFTC needle (TIC and Tew kits; Radionics, Inc., Burlington, MA) was inserted gently using Hartel's anterior approach (15). The needle was passed through the subcutaneous tissue slowly toward the foramen ovale by observing the cerebrospinal fluid and blood leakage or return. A lateral X-ray was used to localize the needle's tip, which should be anterior to the apex of the petrous part of the temporal bone petrous apex (PA) and petro-clival angle placement. In addition to the roentgenogram, localization within the ganglion and nerve branches was confirmed using electrical stimulation at 0.2-1 V (50 Hz, 0.2 ms) during the procedure. RFTC was applied at 65 °C for 72 s. The ciliary reflex (masseter function) was carefully and continuously monitored during and after the stimulation and lesioning process. All of the patients were hospitalized for 24 h and pain and vital signs were monitored. The patient was discharged the next day.

Measurements and Outcome Parameters

The RFTC in our study included four parameters. The first parameter was the distance between PA and the needle tip reaching the Gasserian ganglion in the sagittal plane, second was the distance between PA and the dorsum sellae in the sagittal plane, third was the ratio of the first parameter to the second parameter, and fourth was the angle between PA and the dorsum sellae and line depicting the needle pathway. All parameters were measured on roentgenograms (Figures 1 and 2).

All patient data were reviewed retrospectively for in-hospital complications, including those encountered during the interventional and post-interventional periods. The success of the intervention was assessed based on the degree of pain relief obtained. In the 2 months following surgery, patients were asked to compare their postoperative pain to the pre-procedural pain. Patients with complete pain relief and those with partial

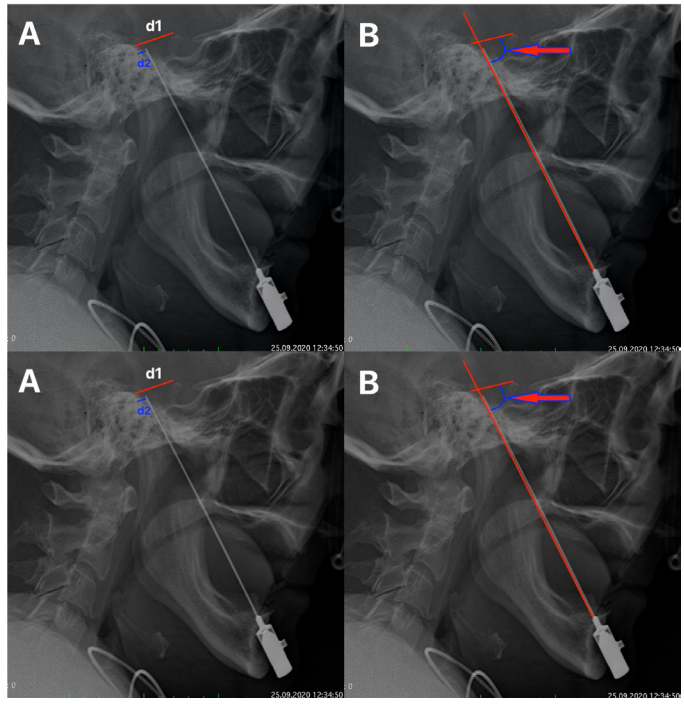

Figure 1: A) Distance parameters on the lateral X-ray of a patient: d1 (red line), the distance between the petrous apex and dorsum cella and d2 (blue line), the distance between the needle tip and petrous apex. The d1:d2 ratio was measured. **B)** The angle between the line joining the petrous apex and dorsum sella and the trajectory of the needle (arrow)

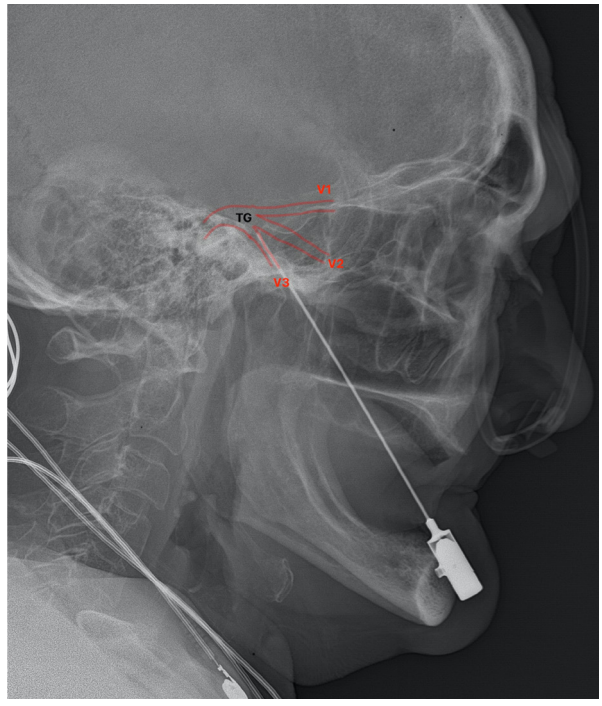

Figure 2: Trajectory and branching pattern illustration of the trigeminal nerve on lateral X-ray. V1: the ophthalmic branch, V2: the maxillary branch, and V3: the mandibular branch of the trigeminal nerve

TG: Trigeminal ganglion

satisfactory pain relief which could be controlled with medical therapy were classified into the "successful procedure" group and others into the "unsuccessful procedure" group. The medical records of the patients in the "unsuccessful procedure" group were re-evaluated for further treatment options, including repetition of the RFTC.

Statistical Analysis

Statistical analysis was performed using IBM SPSS for Windows 20.0 (SPSS Inc., Chicago, IL, USA). Continuous parametric variables are expressed as mean ± standard deviation, median (minimum-maximum). The Shapiro-Wilk test was used to define the conformity of continuous parametric data to normal distribution. The statistical significance of the differences in angle and length variables between the groups was determined using the Mann-Whitney U test. Correlations were analyzed using the Kruskal-Wallis analysis of variance tests. A p-value of <0.05 was considered statistically significant.

Results

Between January 2019 and December 2022, a total of 121 patients underwent RFTC at the neurosurgery polyclinic and enrolled in the study. Two patients were diagnosed with platybasia and excluded from the study. Among the 119 patients, the etiology in 110 was idiopathic, 1 was classical, and 8 was secondary trigeminal neuralgia. The mean age of the patients was 55.94±14.25 years; the minimum age was 21 years, and the maximum age was 87 years. The right side (54.6%) and V3 sensory division (47.1%) were the most commonly affected. The patient characteristics are presented in Table 1. Among the 119 patients, only 2 had procedural complications. One patient developed meningitis and recovered with medical therapy. The other patient had ipsilateral lateral gaze limitation for 3 months, which recovered spontaneously.

Following the RFTC, 58 patients (48.7%) recovered completely, 20 patients (16.8%) experienced partial satisfactory pain relief which could be controlled with medical therapy, and 41 (34.5%) patients had unsatisfactory pain relief. The effects of RFTC on the trigeminal neuralgia pain levels were approximately 65.5% were considered to be successful and 34.5% were unsuccessful. During the 2 months postoperatively, 20 patients with satisfactory pain relief used carbamazepine.

The Mann-Whitney U test was utilized to assess the difference in the parameters between the successful and unsuccessful procedures. There was a statistically significant difference in the PA-dorsum sellae distances between the successful and unsuccessful procedure groups (p<0.05). There was no statistically significant difference in the other three parameters between the two groups (Table 2). The ratio of the two procedural distances was investigated to define the relation between the parameters and the success of the procedure. ROC analysis was performed between PA-needle tip distance and PA-

Table 1: Demographic characteristics of the patients

Characteristic (n=119)	
Age, mean ± SD and Median (Min.-Max.)	55.94±14.25; 58 (21-87)
Sex, n (%) Male Female	 80 (67.3) 39 (32.7)
Side, n (%)	
Right	65 (54.6)
Left	54 (45.4)
Pain distribution, n (%)	
V1	3 (2.5)
V1-V2	7 (5.9)
V1 + V2 + V3	12 (10.1)
V2	11 (9.2)
V2 + V3	30 (25.2)
V3	53 (47.1)

V1: Trigeminal nerve ophtalmic branch, V2: Trigeminal nerve maxillar branch, V3: Trigeminal nerve mandibular branch, Min.-Max.: Minimum-maximum, SD: Standard deviation

Table 2: RFTC procedure parameters

	Successful procedures (n=78) Mean ± SD Median (Min.-Max.)	Unsuccessful procedures (n=41) Mean ± SD Median (Min.-Max.)	p-value
Angle between needle and PA-dorsum sellae lines	66.63±8.31 67.40 (36.31-89.84)	68.24±8.51 67.82 (42.80-81.92)	0.209
PA-tip of the needle distance	7.92±5.30 6.47 (2.01-32.10)	11.78±28.09 6.22 (2.69-185.89)	0.920
PA-dorsum sellae distance	32.92±10.35 32.10 (11.50-80.50)	33.63±31.62 28.70 (8.06-225.79)	0.039
PA-tip of the needle distance/ PA-dorsum sellae distance	0.24±0.11 0.22 (0.06-0.80)	0.28±0.17 0.23 (0.09-0.82)	0.350

PA: Petrous apex, RFTC: Percutaneous trigeminal radiofrequency rhizotomy, Min.-Max.: Minimum-maximum, SD: Standard deviation

dorsum sellae distance and are presented in Figure 3. Youden analysis of the area under the curve parameters had a cutoff value of <0.20 (Table 3).

Comparison of the successful and unsuccessful groups according to 0.20 cut-off using the chi-square test is presented in Table 4. The success rate of the operation with ratio <0.20 was 63% and with ratio >0.20 was 39.7%. In this study, the success rate was higher in the patients with ratio <0.20 than in those with ratio >0.20.

Discussion

Despite other surgical applications and medical treatments, RFTC is frequently practiced in neurosurgical clinics. Easy applicability and high success rates make RFTC a valid procedure (12,16,17). However, the procedure's success depends highly on the anatomical knowledge of the surgeon, the location of the needle tip, and gasserian ganglion localization. This study focused on the relationship between "easy-to-define" radiographic parameters and RFTC success.

RFTC, glycerol rhizotomy, and percutaneous balloon compression are percutaneous techniques for the surgical treatment of trigeminal neuralgia. Most of these procedures use Hartel's technique to reach the foramen ovale with a catheter (18). This technique requires the identification of certain anatomical landmarks, including the angle of the mouth, coronoid process of the mandible, external acoustic meatus, zygomatic arch, and foramen ovale. Our study used osseous anatomical parameters, such as petrous apex and dorsum sellae, that were identified on lateral roentgenographs. We aimed to determine whether the distances of these two anatomical landmarks from the catheter tip can predict the success of the interventions. Proportional relations of the distance of the catheter tip from the petrous apex and dorsum sella reflect the probability of more effective procedures, such as approaching the petrous apex in the horizontal plane. There are similar morphometry studies on the relationship between various anatomic landmarks and RFTC. Tatli and Sindou (19) performed a clinical survey and assessed the distances between two anatomical landmarks: petrous apex and external acoustic meatus. Similar to our study, they reported a significant correlation between the proportional changes in distances and procedure efficiency. Zdilla et al. (20) performed an anatomical study using 139 dry human crania to define the angular relationship between the boundaries of foramen ovale and trigeminal impression (21). They reported that angular adjustments during the procedure aid physicians in targeting specific regions of the trigeminal ganglion. Using another method, Huang et al. (17) measured the inter-structural distances between the foramen ovale and trigeminal cistern on

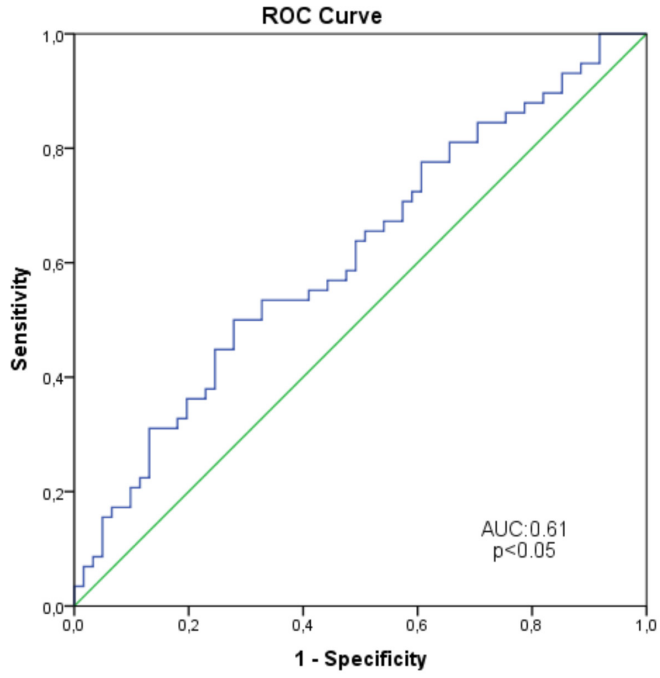

Figure 3: ROC curve showing the relationship between the PA-needle tip distance and PA-dorsum sellae distance

ROC: Receiver operating characteristic, AUC: Area under curve, PA: Petrous apex

Table 3: Prognostic performance of PA-needle tip distance/PA-wall distance ratio in the prediction of procedural success

	AUC 95% CI	p-value	Cut-off	Sensitivity (95% CI)	Specificity (95% CI)	PPV	NPV
PA-tip of the needle distance/PA-dorsum sellae distance	0.61 0.51-0.71	0.033	**<0.20**	0.50 (0.37-0.62)	0.72 (0.60-0.82)	0.63 0.53-0.71	0.60 0.51-069

PA: Petrous apex, AUC: Area under curve, CI: Confidence interval, PPV: Positive predictive value, NPV: Negative predictive value

Table 4: Distribution of a PA-needle tip distance/PA-wall distance ratio of <0.20 and >0.20 among patients who have undergone successful and unsuccessful procedures

		Successful		Unsuccessful		
		n	%	n	%	p-value
PA-tip of the needle distance/PA-dorsum sellae distance	<0.20	29	63	17	37	0.013
	>0.20	29	39.7	44	60.3	

PA, petrous apex

magnetic resonance and computed tomography images. We believe that all these parameters, including the angle, distance, and proportion measurements, support the success of RFTC; thus, these should be used more frequently.

Craniovertebral junction abnormalities should be considered. Among these abnormalities, basilar impression or platybasia is seen more frequently in patients with trigeminal neuralgia (22,23). Platybasia, the abnormal flattening of the skull base, can be the main cause of the disorder (24). The flattening of the skull base and the accompanying anatomical differentiations can cause procedural difficulties, such as needing to change the needle angle. In an RFTC performed under normal conditions, it is expected that a PA-dorsum sellae distance and PA-needle distance ratio of <20% will increase the success rate of the procedure. Although this is difficult to achieve in patients with platybasia, the principle is valid for all patients, regardless of the etiology. Considering these difficulties and differences in the study design, we decided to exclude patients with platybasia since the efficacy of RFTC in those patients is a separate issue that should be examined in future studies.

Trigeminal neuralgia is classified into three main groups according to the etiology: idiopathic, secondary, and classical (7,8). Most of the patients included in our study (n=114) were diagnosed with idiopathic trigeminal neuralgia. Among others, only 1 was diagnosed with secondary trigeminal neuralgia due to a cerebellopontine angle tumor, and 4 with classical trigeminal neuralgia. The idiopathic etiology dominance conforms to the characteristics of the other trigeminal neuralgia study groups (5,12). Patients with trigeminal neuralgia are first diagnosed in the 6th decade of life and are predominantly females (4,25). The mean age and median age of our study population were 55.94±14.25 and 58, respectively, which is comparable to the findings of previous studies. However, in our study, more males were diagnosed with trigeminal neuralgia than females. We believe that the sex difference in our study does not affect the study results in terms of procedure-related anatomical parameters.

Trigeminal neuralgia may present with different characteristics based on the pain type, duration, and area of distribution. This disorder mostly affects the maxillary and/or mandibular branches and rarely affects the ophthalmic branch of the trigeminal nerve (1,4). In our study, only three patients had symptoms in the ophthalmic nerve-supplied area, which is consistent with the findings in the literature. The distribution of pain from the least to the most common is as follows: ophthalmic, ophthalmic and maxillary, maxillary, mandibular and maxillary, and mandibular regions; pain in the lower half of the face was more common than in the upper half of the face.

Trigeminal neuralgia management includes medical and surgical treatments. Pharmacologic treatments are the first choice among the medical modalities (4) and are sufficient for pain relief and long-term follow-up (26,27). Surgical or interventional procedures are performed after unsuccessful or insufficient medical options and are not recommended in the early course of the disease (24,28-30). RFTC is a reasonable interventional option for trigeminal neuralgia. In our study, RFTC was applied to patients with trigeminal neuralgia in whom medical treatment failed, as per the current literature. Fluoroscopy, computed tomography, magnetic resonance imaging, and virtual reality techniques have been used to accurately locate the needle to successfully perform RFTC (14,31-33). Among all these options, the use of lateral roentgenograms for the positioning of the needle is the most commonly used assistive radiological method (19). Lateral roentgenograms are preferred by physicians because of their low cost, easy visualization, and high efficiency with minimal radiation exposure (16,34). The success rate (65.5%) was acceptable in our study, thus, we believe that the success of the process can be further increased by the implementation of similar anatomical parameters.

RFTC is an invasive percutaneous procedure performed in a region that includes vital anatomical structures. Iwanaga et al. (18) reported the catheter penetrates only the superior head of the lateral pterygoid muscle and does not penetrate any other important neurovascular structure in a Hartel procedure-guided RFTC (18). The rate of unsuccessful foramen ovale cannulation procedures is reportedly 2-5%, and anatomical variations increase this rate (1,18,20,35). In this situation, penetration of neighboring structures results in intra and extra-cranial complications (12,36). Bleeding, a complication of this procedure, may develop due to damage to the internal carotid artery, maxillary artery and its branches, and pterygoid venous plexus. In addition to bleeding, absent corneal reflex, masticator paresis, chewing difficulty, anesthesia dolorosa, disabling dysesthesia, and visual impairments have been reported as complications of the procedure (18,19,37). During our study period, 2 patients developed complications. One patient developed meningitis; this is the first documented report of meningitis in this procedure. The other patient developed a lateral gaze deficit, which may have developed due to ipsilateral abducens nerve damage because of stretching or compression rather than a complete rupture. This complication emphasizes the importance of anatomical knowledge competency among physicians performing the RFTC and indicates the need for more morphometric studies on RFTC procedures.

Study Limitations

The limitation of the study was evaluation of a small population of trigeminal neuralgia patients treated with RFTC. Larger patient population data will result in more accurate interpretation of results. In addition, long-term evaluation

of patient results will be beneficial in terms of treatment effectiveness.

Conclusion

In conclusion, the success of the RFTC procedure increases as the ratio of the PA-needle tip distance to the PA-dorsum sellae distance decreases (0.20 coefficient). We believe that this ratio is an easy-to-define, reliable, and simple parameter. Because the numbers of studies on the RFTC method are limited, further cadaveric and clinical studies should be performed to identify the safe penetration points and angles to prevent damage to the neighboring vital structures.

Ethics

Ethics Committee Approval: The study was approved by the Ethics Committee of the Liv Hospital Ankara, Türkiye (approval number: 2022/003, decision no: 003).

Informed Consent: Written informed consent was obtained from the patients.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: Y.E.G., A.S., Concept: Y.E.G., A.S., Design: Y.E.G., Data Collection and Processing: Y.E.G., N.S., Analysis or Interpretation: Y.E.G., N.S., A.S., Literature Search: Y.E.G., N.S., Writing: Y.E.G., N.S.

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