Systematic Review

Effectiveness of Radiofrequency Ablation for Treatment of Glossopharyngeal Neuralgia: A Systematic Review of the Current Literature

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Background: Glossopharyngeal neuralgia (GPN) is a rare cause of facial pain that has an incidence of less than one per 100,000 people. The excruciating stabbing pain experienced by patients with GPN can be debilitating, leading to difficulties in activities of daily living, such as eating and speaking. As a result, there has been a recent increase in research on the effectiveness of radiofrequency ablation (RFA) for treating GPN.

Objective: The objective of our study was to evaluate the effectiveness of (RFA for treating GPN while examining its impact on patients' quality of life and assesses for any associated side effects.

Study Design: The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) model was employed to identify articles from 2 comprehensive medical databases. The patient outcomes and numbers from each article were aggregated and calculated in order to determine the percent efficacy of RFA for treating pain associated with GPN.

Methods: In this systematic review, the PRISMA review model was utilized to search through the PubMed and EMBASE databases. A comprehensive literature review was conducted. Of the initial 1,580 articles identified, 18 articles were included for analysis. Studies included in this systematic review encompassed idiopathic cases and secondary causes, such as an elongated styloid process, oropharyngeal cancers, and postsurgical/traumatic pain.

Results: Of the 288 patients treated with RFA, 231 experienced relief or complete resolution of pain, yielding an efficacy rate of 80.2%. Most of the patients experienced immediate pain relief after RFA; however, some patients reported numbness, dysphagia, and changes in taste. Our study examines the potential use of RFA as a minimally invasive and effective treatment for GPN.

Limitations: Limitations of our study include the absence of comparisons between different types, modes, and settings of RFA procedures. The use of only 2 medical databases is another limitation. Finally, our systematic review does not include any randomized controlled trials.

Conclusion: RFA is efficacious in treating GPN with over 80% of patients experiencing postprocedure pain relief. However, further research in the form of clinical and controlled trials is needed to contribute to a better understanding of RFA's long-term outcomes for patients with GPN.

Key words: Glossopharyngeal neuralgia, facial pain, radiofrequency ablation, facial pain, chronic pain management, pain measurement

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Glossopharyngeal neuralgia (GPN) is a rare form of neuropathic facial pain that presents with spasmodic attacks to the posterior tongue, jaw, ears, tonsillar fossa, and other parts of the oropharynx (1,2). The pain is described as short and intense episodes of stabbing pain, which is often unilateral and sudden in nature (2). The auricular and pharyngeal branches of the glossopharyngeal (IX) and vagus (X) cranial nerves are affected in glossopharyngeal neuralgia, where they are typically the root cause of the paroxysmal sharp pain that patients experience (1,3). Although quite rare with an annual incidence of 2 to 7 per one million individuals, known causes of this disease is common in patients with oropharyngeal cancers (3,4). However, most of the GPN cases are idiopathic (5). Other causes of the disease can be secondary to an elongated styloid process, cancer, infection, trauma, vascular compression, inflammatory disorders, and more (2,5).

Common medical treatment options for GPN include anticonvulsant drugs, such as carbamazepine, gabapentin, or eslicarbazepine (1,2,4). Procedural interventions can be done if patients do not respond to these medications, such as microvascular decompression, gamma knife surgery, chemical neurolysis, cryoneuroablation, and radiofrequency ablation (RFA) (2,6-8).

RFA is a technique that directly destroys the targeted nerves through heat generated from radiofrequency waves (9). The heat destroys the affected nerves, which in turn disrupts the pain signals from making their way to receptors, thus alleviating the symptoms present in patients experiencing severe pain (10). RFA can be applied to the nerves in 2 different ways, either in a pulsed (pulsed radiofrequency [PRF]) or continuous (continuous radiofrequency [CRF]) manner (11). Typically, PRF delivers short episodes of heat to the nerve in intervals of 20 milliseconds every 500 milliseconds, while keeping the temperature at lower than 42°C (12). CRF delivers a constant flow of energy while keeping the temperature between 60°C and 80°C (12,13).

RFA is an effective minimally invasive procedure that treats GPN safely without major complications to patients (14). Although some patients may experience numbness, dysphagia, changes in taste, and hoarseness, a majority of patients respond well to RFA and experience pain relief almost immediately to treatment; many of them experience persistent relief for years as well (13,14). The objective of our systematic review was to further evaluate the effectiveness of RFA in treating patients with GPN, while examining secondary factors like quality of life and side effects associated with RFA treatment.

Methods

Study Design

The researchers in this study used the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) review model to retrieve articles for this systematic review (15). Two vast databases were implemented in our comprehensive search. We retrieved articles through PubMed (MEDLINE) and Excerpta Medica (EMBASE). All of our searches were restricted to articles in English. Five eliminatory screens under the PRISMA methodology guidelines were referenced in order to select articles for inclusion (15).

The broad search terms that were used consisted of the phrase "glossopharyngeal neuralgia treatment" and "glossopharyngeal neuralgia radiofrequency." The database searches on PubMed (MEDLINE) yielded 863 results and 31 results for the 2 search phrases, respectively, with years ranging from 1941 to 2023. The database searches on EMBASE yielded 613 results and 73 results for the 2 search phrases, respectively, with years ranging from 1974 to 2023. During our screening, some areas for inclusion included nonsurgical treatments for GPN and the application of RFA (either continuous or pulsed) for the disease. Areas for exclusion included but were not limited to surgical treatments for GPN, other procedures that did not involve the use of RFA, facial pain disorders that were not related to the glossopharyngeal nerve, and more. The criteria for inclusion and exclusion for our systematic review are displayed in Fig. 1.

Study Selection

Step One involved the initial screening of articles solely based on whether or not their titles pertained to our focus. Afterwards, the abstracts were screened based on their relevance to our topic. Next, the reviewers assessed the entirety of each article to determine if they were appropriate for this systematic review. After these stages of screening, all of which are demonstrated in Fig. 1, the reviewers identified qualitative and quantitative information from 18 relevant articles. These 18 articles were used to create the systematic literature review. The titles, results, and key findings regarding the efficacy of RFA in treating patients with GPN are displayed in Table 1.

In the last step, we eliminated articles that did not

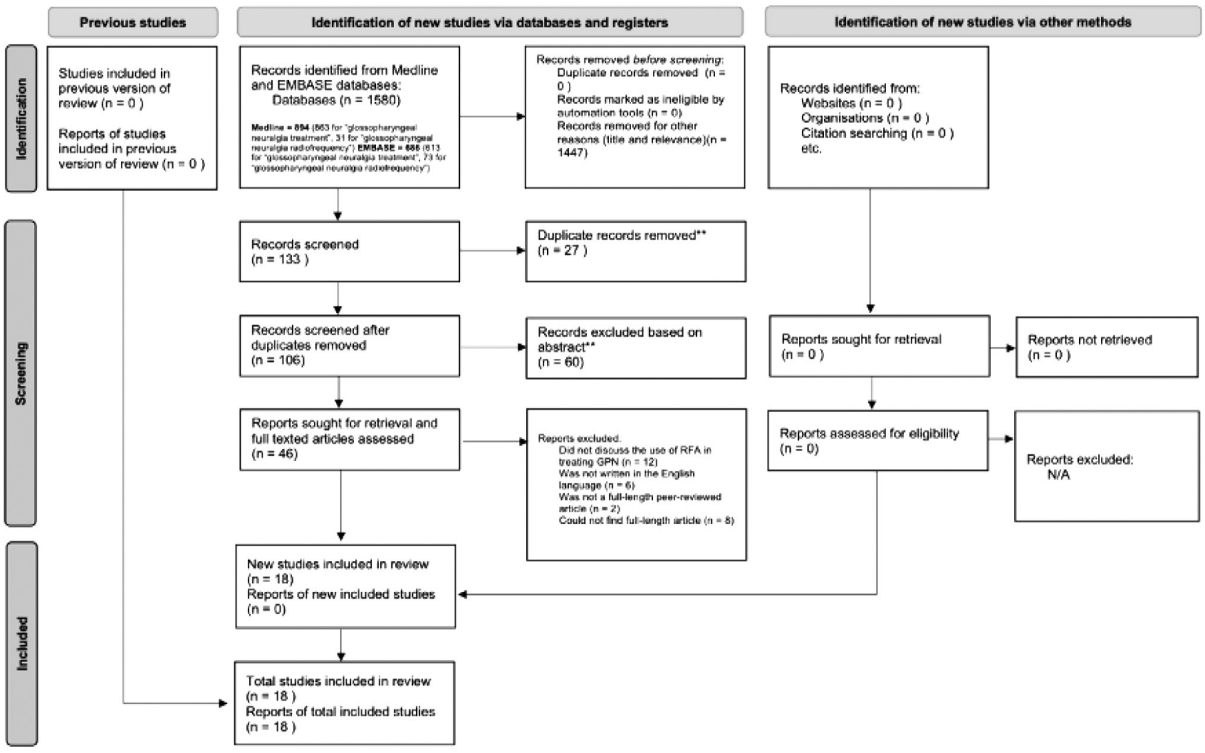

Fig.1. *Study flow chart.*

discuss the use of RFA in treating patients with GPN, that were not written in English, and that did not yield full peer-reviewed publications. Three reviewers independently screened the articles in the 2 databases in order to obtain the final list of articles for our study, and the entire team agreed on the final selection of the literature.

Once the reviewers completed the screening and identified the articles for the systematic review, the articles were categorized into their topics of assessment. These articles were divided into the use of RFA for various causes of GPN, such as patients who developed the disease secondary to an elongated styloid process, cancer, trauma, and other, idiopathic origins.

This systematic review has not been registered in the Prospective Register of Systematic Reviews (PROSPERO). The protocol and data are available upon request.

Quality Assessment and Data Abstraction

The risk of bias for each of the articles included in this systematic review were assessed by 3 independent reviewers. Another senior researcher oversaw and helped resolve disagreements during this process as well. Some characteristics of the articles that were examined included their methods of randomization, deviations from intended interventions, missing outcome data, the measure of the outcome, and selection of the reported results.

Articles that were case series, observational studies, and interventional studies were assessed for bias in accordance with the National Institutes of Health recommended tool used to assess for quality (Tables 2-4) (16). The quality assessment of these studies is displayed in Tables 2, 3, and 4.

The study quality assessment tool provided by the National Institutes of Health consists of 9 questions for case series and 14 questions for observational studies and interventional studies that evaluate the credibility of articles used in a systematic literature review. The score that is received from this survey for case series determines the quality of the study with a score between 7-9 being good, 5-6 being fair, and 0-4 being poor. The score that is received from this survey for observational and interventional studies determines the quality of the study with a score be-

Table 1. *Radiofrequency ablation (RFA) in patients with glossopharyngeal neuralgia.*

Article	Study Type	Year	Nerve Targets	Number of patients treated	Number of Patients with Pain Relief	Mode of RFA	Total Percent with Pain Relief	RFA Efficacy	Key findings	Risk of Bias Assessment
Aggarwal, et al (27)	Case Report/ Editorial	2020	Glossopharyngeal Nerve	1	1	RFA 50°C - 70°C	100%	Patient's NRS-11 score started as 5-6/10, but dropped to 3/10, 1/10, 0/10 and 0/10 at 2 weeks, 1 month, 6 months, and 1 year after RFA.	Patient's pain completely resolved by 1 year.	Good
Arbit, et al (32)	Case Report	1991	Glossopharyngeal Nerve	1	1	RFA 60°C - 90°C	100%	Patient was pain free after the procedure.	Patient had pain that led her to lose 24 pounds. After CT-guided PRF, she became pain free.	Good
Arias, et al (33)	Case Report	1986	Glossopharyngeal Nerve	2	2	RFA	100%	Both patients had complete resolution of pain.	The 2 patients became pain free without any effects to the nerves.	Good
Bharti, et al (22)	Prospective interventional clinical trial	2017	Glossopharyngeal Nerve	25	23	PRF at 42°C	92%	Patients had pain relief and overall satisfaction score of 7.	Patients got 3 pulses of PRF treatment, and relief with pain, nausea, and sleep issues.	Poor
Chua, et al (29)	Case Report/ Editorial	2011	Glossopharyngeal Nerve	2	2	PRF	100%	1 patient was completely pain free and the other had consistent pain relief.	Both patients remained pain-free after follow-up a few months later.	Fair
Jia, et al (13)	Retrospective Observational Study	2020	Glossopharyngeal Nerve	30	23	PRF at 42°C	76.60%	NRS-11 score dropped to 4, showing pain relief. Initial relief was 28/30 (93.3%) within one month.	PRF was CT guided. 22 patients had oropharynx pain, 3 had pain in ear, and 12 with pain below mandible. 5 patients had recurrence, 2 of which continued PRF again. No recurrence afterwards.	Fair
Khan, et al (3)	Case Report	2010	Glossopharyngeal Nerve	1	1	PRF at 42°C, RFA at 80°C	100%	VAS was originally 9-10, but dropped to 0/10 after RFA.	Pain came back after 6 hours (VAS 9-10 after 24 hours) following PRF. Radiofrequency thermocoagulation was then performed and VAS was 0-2 a few weeks after the procedure with almost complete pain resolution.	Good

Table 1 cont. *Radiofrequency ablation (RFA) in patients with glossopharyngeal neuralgia.*

Article	Study Type	Year	Nerve Targets	Number of patients treated	Number of Patients with Pain Relief	Mode of RFA	Total Percent with Pain Relief	RFA Efficacy	Key findings	Risk of Bias Assessment
Mollinedo, et al (21)	Case report	2012	Glossopharyngeal Nerve (Mandible nerve initially)	1	1	PRF at 42°C	100%	Patient pain significantly decreased (initially 6-7/10).	Patient initially had a nerve block to the mandible nerve. However, he was later diagnosed with Eagle syndrome (elongated styloid process), so a glossopharyngeal nerve block was performed. PRF was performed after for long-term treatment.	Good
Ori, et al (24)	Case Series	1985	Glossopharyngeal Nerve	9	8	RFA at 60°C - 65°C	88.90%	5 of the 9 patients experienced side effects following the procedures.	Only 1 of the patients experienced pain recurrence and needed 2 more episodes of RFA.	Good
Salar, et al (28)	Case Series	1986	Glossopharyngeal Nerve and Trigeminal Nerve	3	3	RFA at 65°C - 75°C	100%	Experienced pain relief, but none of them had complete resolution.	All of the patients were satisfied and did not experience episodes of pain and did not need morphine.	Good
Salar, et al (23)	Case Series	1983	Glossopharyngeal Nerve	8	8	RFA at 60°C - 65°C	100%	All patients got immediate pain relief.	75% of the cases saw interruptions to the 10th cranial nerve. Hypotension and bradycardia were observed in 6 of the patients.	Good
Shah, et al (26)	Case Report	2003	Glossopharyngeal Nerve	1	1	PRF at 42°C	100%	Pain went from 10/10 to 0/10.	Patient developed pain after a right-sided tonsillectomy. Glossopharyngeal nerve was treated with nerve block and PRF. Pain recurred and PRF was repeated 2 more times over 2 years.	Good
Song, et al (14)	Retrospective Observational Study	2019	Glossopharyngeal Nerve	117	96	RFA at 70°C - 85°C	82.1%	82.1% of patients got immediate relief. Patients who got excellent recovery from pain were 75.9% at 1 year, 63.0% at 3 years, 54.0% at 5 years, 44.2% at 10 years, and 39.3% at 12.5 years.	No mortality seen, only mild symptoms such as dysphagia (26 patients) or lingual numbness (30 patients).	Good
Swain, et al (20)	Case Report	2020	Glossopharyngeal Nerve	1	1	PRF at 42°C	100%	Pain was originally 8-9/10 and pain disability score was 40/70, but was pain free after PRF.	Elongated styloid process compressing glossopharyngeal nerve. Patient originally had a nerve block that helped for 48 hours but RFA under fluoroscopy provided long term relief for the past 14 months.	Good

Table 1 cont. *Radiofrequency ablation (RFA) in patients with glossopharyngeal neuralgia.*

Article	Study Type	Year	Nerve Targets	Number of patients treated	Number of Patients with Pain Relief	Mode of RFA	Total Percent with Pain Relief	RFA Efficacy	Key findings	Risk of Bias Assessment
Telischak, et al (31)	Observational	2018	Glossopharyngeal Nerve	3	2	CRF at 60°C	66.70%	Typical patients with GPN had an NRS-11 score go from 5-6/10 to 0/10. For the patients with atypical GPN, only 1 of them experienced relief.	Mild numbness in the throat was experienced by 2/3 patients (1 typical and 1 atypical patients with GPN).	Good
Thilburg, et al (25)	Case Report	2020	Glossopharyngeal Nerve	1	1	PRF	100%	The patient experienced pain relief, going from NRS-11 scale of 10 to 5 after 2nd PRF treatment.	The patient had bilateral glossopharyngeal neuropathy, where surgery and medication did not help. 3 months after the first PRF, her NRS-11 score was a 6 and 3 months after the second PRF, her NRS-11 score was a 5.	Fair
Wang, et al (6)	Retrospective Observational Study	2016	Glossopharyngeal Nerve	80	63	RFA at 70°C - 85°C	78.80%	At discharge, 78.8% of patients were pain free and 73.2% at 1 year follow up.	Ten patients had the pain come back, with 3 of them completing repeat PRF.	Fair
Zhu, et al (30)	Case Report	2018	Glossopharyngeal Nerve	2	2	CRF at 60°C - 80°C	100%	One patient had complete resolution and the other had pain relief. Tongue numbness lasted several months afterwards.	CT-guided PRF for the first patient followed CRF thermocoagulation. The second patient had CRF as the first choice.	Good

PRF = pulsed radiofrequency; CRF = continuous radiofrequency; VAS = Visual Analog Scale; NRS-11 = Numeric Rating Scale; GPN = glossopharyngeal neuralgia.

tween 11-14 being good, 7-10 being fair, and 0-6 being poor (16).

The case reports in our study were assessed for bias in accordance with the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Case Reports (Table 5) (17). The quality assessment of these studies is displayed in (Table 5). The study quality assessment tool provided by the JBI contains 8 questions that examine the quality, credibility, and risk of bias in case reports. The score that is received from this survey determines the quality of the study with a score between 7-8 being good, 4-6 being fair, and 0-5 being poor (17).

Definitions

Many of the articles in this systematic review assessed the progress of their patients by determining a pain scale score pre- and post-RFA. One common scale used was the Numeric Rating Scale (NRS-11) (18). This tool allows patients to report their pain by selecting a number from a scale of 0-10. From this scale, zero means that the patient has no pain and 10 means that the patient has the most severe pain they have ever experienced (18). Another common scale used across these articles is the Visual Analog Scale (VAS). Similar to the NRS-11 scale, the VAS score comes from a continuous scale with 2 endpoints, ranging from no pain to maximum pain. The VAS score is usually depicted on a 10 centimeter line, where like the NRS-11 scale, zero indicates no pain and 10 indicates severe pain (19).

Results

There are many case reports, case series, and observational studies that have demonstrated the efficacy of RFA in alleviating pain for patients with GPN in the current literature; they are included in our study. Our systematic search yielded only one interventional clinical trial that addressed the use of RFA on the glossopharyngeal nerve. That study demonstrated that CRF and PRF successfully relieved or completely resolved the pain experienced by patients with GPN.

Study Screening

The vast and comprehensive search phrases implemented to retrieve pertinent articles for our systematic literature review produced a total of 133 articles with relevant titles, 27 of which were removed because they were duplicates of other articles. The relevancy of the remaining 106 articles were screened based on their abstracts,; 60 of them were later eliminated from our study selection. Our final screening stage included reviewing the entire text of the remaining 46 articles, resulting in 28 articles being removed. This yielded a total of 18 articles for our systematic review. Some reasons for exclusion during our title, abstract, and full-text screening stages included publications not relevant to treating GPN with RFA, not written in English, and not completely published peer-reviewed articles.

Study Quality

In accordance to the National Institutes of Health tool and the JBI Appraisal Checklist for Case Reports, 13 of the articles included in this review were labeled good quality, 4 were labeled fair quality, and one was labeled as poor quality (16,17).

Study Characteristics

After screening, our systematic review included a total of 18 articles for our study. In these 18 articles, a total of 288 patients with GPN were treated with RFA, either PRF or CRF. Of the patients treated, 231 of them experienced pain relief or complete resolution of their symptoms, which yields an efficacy rate of 80.2% for RFA procedures. The demographics of the patients examined in this systematic review consisted of 159 men and 126 women, although these numbers may not be completely representative as some papers did not specify the gender of their patients. The age of these patients ranged from 22 – 87 years old. In this study, 231 of the 288 patients with GPN experienced pain relief or complete pain resolution after treatment with RFA, producing an efficacy rate that ranges from 66.7% to 100%.

Table 2. *Risk-of-bias assessment of case series.*

	Ori, et al (24)	Salar, et al (23)	Salar, et al (28)
Q1: Was the study question or objective clearly stated?	Y	Y	Y
Q2: Was the study population clearly and fully described, including a case definition?	Y	Y	Y
Q3: Were the cases consecutive?	Y	Y	Y
Q4: Were the subjects comparable?	Y	Y	Y
Q5: Was the intervention clearly described?	Y	Y	Y
Q6: Were the outcome measures clearly defined, valid, reliable, and implemented consistently across all study participants?	N	N	N
Q7: Was the length of follow-up adequate?	Y	Y	Y
Q8: Were the statistical methods well-described?	N	N	N
Q9: Were the results well-described?	Y	Y	Y
Final Quality Score	7	7	7
Rating	Good	Good	Good

Quality Assessment Tool for Clinical Case Series (https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools)

Elongated Styloid Process

Swain, et al (20) and Mollinedo, et al (21) reported 2 case reports on patients who had GPN secondary to an elongated styloid process. The 2 patients reported in these studies had imaging that confirmed the presence of Eagle syndrome. Both were treated with a glossopharyngeal nerve block followed by PRF and experienced pain relief as assessed by their VAS scores (20,21).

Oropharyngeal Cancers/Tumors

Bharti, et al (22) was an prospective interventional clinical trial, Salar, et al (23) was a case series, and Khan, et al (3) was a case report—all of them assessed patients with GPN who experienced oropharyngeal carcinoma. A total of 34 patients were examined between these 3 articles, 32 of whom experienced pain relief or complete pain resolution after being treated with RFA to the glossopharyngeal nerve, yielding an efficacy rate of 94.1% (3,22,23). Ori, et al (24) examined 9 patients (6 of

Table 3. *Risk-of-bias assessment for observational studies.*

	Jia, et al (13)	Song, et al (14)	Telischak, et al (31)	Wang, et al (6)
Q1: Was the research question or objective in this paper clearly stated?	Y	Y	Y	Y
Q2: Was the study population clearly specified and defined?	Y	Y	Y	Y
Q3: Was the participation rate of eligible persons at least 50%?	Y	Y	Y	Y
Q4: Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	Y	Y	Y	Y
Q5: Was a sample size justification, power description, or variance and effect estimates provided?	N	Y	Y	N
Q6: For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	Y	Y	Y	Y
Q7: Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	Y	Y	Y	Y
Q8: For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?	N	N	N	N
Q9: Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y	Y	Y	Y
Q10: Was the exposure(s) assessed more than once over time?	Y	Y	Y	Y
Q11: Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y	Y	Y	Y
Q12: Were the outcome assessors blinded to the exposure status of participants?	N	N	N	N
Q13: Was loss to follow-up after baseline 20% or less?	Y	Y	Y	Y
Q14: Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	N	N	N	N
Final Quality Score	10	11	11	10
Rating	Fair	Good	Good	Fair

Quality Assessment Tool for Observational Studies (https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools)

whom had oropharyngeal tumors) who underwent 11 RFA procedures and found that 5 of them experienced cardiovascular abnormalities, such as lower blood pressure or cardiac dysrhythmias, during the RFA procedure.

Scarring After Surgery/Trauma

Studies by van Tilburg, et al (25), Shah, et al (26), Aggarwal, et al (27), and Salar, et al (28) treated patients who developed GPN after undergoing various kinds of surgery, such as nasal septum surgery, tonsillectomy, and styloidectomy. Chua, et al (29) reported 2 patients who developed GPN, with one developing the condition after a tonsillectomy and the other after her neck was hyperextended. All 8 patients included in these studies were successfully treated with RFA and experienced a decrease in pain, although some of them never got complete resolution of their pain (25-29).

Other

The articles published by Wang, et al (6), Jia, et al (13), Song, et al (14), Zhu, et al (30), Telischak, et al (31), , Arbit, et al (32), and Arias, et al (33) all included patients with idiopathic GPN or GPN with no reported secondary causes. Of the 235 patients, 189 achieved decreased pain or complete pain resolution after RFA treatment. This set of articles yielded an efficacy rate of 80.4% for RFA in patients with GPN.

Discussion

The idea of using radiofrequency to raise temperatures in the body was first introduced in 1891 by D'Arsonval (34). It was not until 1975 that the use of RFA was popularized after it was used to terminate nerves and disrupt pain signals in patients who had chronic low back pain without an identifiable cause (35). Today, the use of RFA is widespread across multiple medical specialties in treating various diseases, such as thyroid nodules, spinal metastasis, liver cancer, atrial fibrillation, uterine fibroids, and chronic pain (34–37).

The main objective of RFA in treating these con-

ditions is destroying cells, nerves, and tissue under thermal heat, which promotes tumor elimination and pain relief (10). Although RFA has been observed as an effective means for treating these vast conditions, not many studies have assessed performing RFA for GPN, a facial neurological disorder that has been traditionally treated with medications and surgical intervention. In our systematic review, we screened and selected articles that detail performing RFA for treating GPN in order to evaluate its effectiveness in treating this condition.

Nerve Compression

Swain, et al (20) reported a 66-year old man who had severe pain in his right neck, mandible, and ear. The patient rated the pain as an 8-9/10. X-ray and computed tomography (CT) later confirmed styloid process hypertrophy. Following a glossopharyngeal nerve block that provided temporary relief, PRF was performed for 3 cycles with a frequency of 2 Hz and temperature of 42°C. The patient recovered successfully from the procedure and had complete resolution of pain (20).

Mollinedo, et al (21) reported a 59-year-old man who had pain in the left side of his neck, mandible, and temporoparietal area. The patient experienced a persistent dull pain to his oropharynx and sudden onset of sharp pain when he was eating or moving his neck. He originally received a nerve block to the trigeminal nerve, but after CT imaging confirmed an elongated styloid process, known as Eagle syndrome, the patient received nerve blocks to the glossopharyngeal nerve followed by PRF treatment at a frequency of 2 Hz and temperature of 42°C (21). His preoperative VAS score was 6-7/10. He received significant postprocedure pain relief. He received another PRF treatment and his pain relief lasted for more than 90 days (21).

Oropharyngeal Cancers/Tumors

One case report, one prospective interventional clinical trial, and one case series evaluated patients who received treatment for GPN secondary to oropharyngeal cancers or tumors (3,22,23).

Khan, et al (3) reported a 72-year-old man who had squamous cell carcinoma involving his tongue, with a reported VAS score of 9-10/10. PRF with a frequency of 2 Hz and temperature of 42°C was performed on the glossopharyngeal nerve, and although the patient experienced immediate pain relief, the pain recurred after 6 hours. The patient then underwent 2 cycles of RFA at 80°C and experienced a large decrease in pain, with a VAS score of 0-2/10 (3).

Table 4. *Risk-of-bias assessment for clinical trials.*

	Bharti, et al (22)
Q1: Was the research question or objective in this paper clearly stated?	N
Q2: Was the study population clearly specified and defined?	N
Q3: Was the participation rate of eligible persons at least 50%?	Y
Q4: Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	Y
Q5: Was a sample size justification, power description, or variance and effect estimates provided?	N
Q6: For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	Y
Q7: Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	Y
Q8: For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?	N
Q9: Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y
Q10: Was the exposure(s) assessed more than once over time?	Y
Q11: Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y
Q12: Were the outcome assessors blinded to the exposure status of participants?	N
Q13: Was loss to follow-up after baseline 20% or less?	Y
Q14: Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	N
Final Quality Score	8
Rating	Poor

Quality Assessment Tool for Interventional Studies (https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools)

Bharti, et al (22) examined 25 patients with ages ranging from 18-65 who had cancer and severe pain to their oropharynx. These cancers ranged from carcinomas in their tongues to tonsils. They reported that 76% of these patients had tongue pain, 16% had tonsillar fossa pain, and 8% had tonsil pain. Radiation treatment to the ipsilateral ear and mandibular

Table 5. *Risk-of-bias assessment of case reports.*

	Arbit, et al (32)	Arias, et al (33)	Aggarwal, et al (27)	Chua, et al (29)	Khan, et al (3)	Mollinedo, et al(21)	Shah, et al (26)	Swain, et al (20)	Tilburg, et al (25)	Zhu, et al (30)
Q1: Were patient's demographic characteristics clearly described?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q2: Was the patient's history clearly described and presented as a timeline?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q3: Was the current clinical condition of the patient on presentation clearly described?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q4: Were diagnostic tests or assessment methods and the results clearly described?	Y	N	Y	N	N	Y	Y	Y	N	Y
Q5: Was the intervention(s) or treatment procedure(s) clearly described?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q6: Was the post-intervention clinical condition clearly described?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q7: Were adverse events (harms) or unanticipated events identified and described?	Y	Y	Y	N	Y	N	Y	N	N	N
Q8: Does the case report provide takeaway lessons?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Final Quality Score	8	7	8	6	7	7	8	7	6	7
Rating	Good	Good	Good	Fair	Good	Good	Good	Good	Fair	Good

The Joanna Briggs Institute Critical Appraisal Checklist for Case Reports (17).

angle was administered to 84% of these patients (22). Three cycles of PRF with a frequency of 2 Hz and temperature of 42°C were performed for these patients. Of the 25 patients examined, 23 experienced immediate posttreatment pain relief (92%) with RFA (22).

The case series by Salar, et al (23) examined 5 patients with oropharyngeal tumors and 3 who had essential pain from GPN (23). The 5 patients with oropharyngeal tumors experienced persistent pain and sudden episodes of increased pain when swallowing, whereas the 3 patients with essential pain from GPN experienced sharp pain during swallowing with radiation to the ear canal. All 8 patients, ages 41-68, experienced immediate posttreatment pain relief with RFA at 60°C - 65°C to the glossopharyngeal nerve. However, only the 3 patients with essential pain experienced complete pain resolution, while the other 5 patients still experienced some constant tonsillar pain, although they did receive significant pain relief (23). Three of those 5 patients with oropharyngeal tumors also had associated trigeminal pain, which required them to receive RFA to the trigeminal nerve as well. Complications associated with the procedures included interruptions to the vagus nerve in 75% of the cases;6 of the patients experienced hypotension and bradycardia as well (23).

Another case series by Ori, et al (24) assessed complications in patients with GPN who received RFA treatment. In this study, 9 patients with GPN received a total of 11 RFA procedures; one patient required 2 additional procedures. Out of the 9 patients, 6 had GPN secondary to oropharyngeal tumors while the other 3 had essential GPN. They reported hypotension, bradycardia, asystole, cardiac dysrhythmias, seizures, and syncope. This study found that 6 of the 11 procedures (5 of the 9 patients) experienced some form of these cardiovascular and cerebral side effects following RFA. All of the patients were successfully treated for these complications during the procedures and there were no additional problems that arose posttreatment (24).

Postsurgical/Trauma Pain

Four case reports and one case series examined patients who developed GPN following surgery (25-29).

Tilburg, et al (25) reported a 41-year-old woman who developed constant pressure pain to her throat 120 days postsurgery on her nasal septum and inferior concha. She was later diagnosed with bilateral glossopharyngeal neuropathy, and after trying analgesic medications, she received PRF to her glossopharyngeal nerves bilaterally. The patient's original pain score was a 10/10, but this dropped to a 6/10 at 90 days post-PRF treatment, and a 5/10 following the second PRF treatment. The patient experienced relief to her pain behind her ears and pain during swallowing (25).

In the study by Shah, et al (26), an 84-year-old woman experienced sharp pain to the right oropharynx, jaw, tongue, and ear following a tonsillectomy to her right side. Following a nerve block, PRF to the right glossopharyngeal nerve was performed with a frequency of 2 Hz and temperature of 42°C. After the first procedure, the patient's pain score decreased to 0/10. However, after 8 months, the pain recurred; a second PRF procedure was performed and her pain completely resolved (26).

Aggarwal, et al (27) reported a 38-year-old woman who developed pain to her tonsils, the base of her tongue, and ears 6-8 months after a partial styloidectomy. She rated her pain as a 9-10/10. RFA was performed to the ninth cranial nerve (glossopharyngeal nerve) at a frequency of 50 Hz frequency and temperature of 50°C-70°C. The patient received significant pain relief, reporting her pain to be 3/10, 1/10, 0/10, and 0/10 at 2 weeks, one month, 6 months, and one year (27).

In Salar, et al (28), 5 patients underwent surgical excision and radiation therapy for oropharyngeal tumors. All patients experienced severe postsurgical pain worsened with chewing and talking. The 5 patients all received RFA treatment to the fifth cranial nerve (trigeminal nerve), 3 of whom later received secondary treatment to the ninth cranial nerve. All 5 patients, especially the 3 patients with GPN, reported immediate postprocedure pain reduction, although none of them experienced complete pain resolution (28). However, it is important to note that one patient required 2 additional RFA procedures performed to the glossopharyngeal nerve 4 and 6 months after the first encounter (28).

Another case report by Chua, et al (29) reported a 41-year-old woman who developed GPN after a hyperextended neck accident and another woman who developed GPN after undergoing a tonsillectomy. After treatment with PRF, the first patient had complete pain resolution while the second patient had significant pain reduction (29).

Other

Wang, et al (6) conducted a retrospective observational study in 80 patients, however, their paper did not include a cause for the onset of GPN. Of these 80 patients, 63 (78.8%) did not have any pain following a CT-guided PRF procedure. At one year, the percentage of patients who still had "excellent" pain relief was 73.2%, but this number dropped to 43.0% at 10 years (6). During this time, pain recurred only in 10 patients, 3 of whom underwent PRF again. Other things to consider from this study include operational complications, where 11 experienced dysesthesia in the area of anesthesia, 5 experienced dysphagia, and 2 experienced a diminished gag reflex. No patients died as a result of the PRF procedure (6).

A retrospective observational study by Jia, et al (13) reported 30 patients who had idiopathic GPN. Of the 30 patients, 11 were men and 19 were women, where the range of GPN onset was 20-83 years, with an average age of 55.1 ± 16.2 years. CT-guided PRF was performed on these patients and 28/30 (93.3%) of them experienced immediate pain relief (13). The preoperative median NRS-11 score was 7; this dropped to 4 postprocedure. Only 5 of the patients experienced pain recurrence at 13, 33, 51, 60, and 84 months, respectively, after the initial procedure (13).

Song, et al (14) conducted a retrospective observational study that looked at 117 patients. Similar to Jia, et al (13), these patients had idiopathic GPN and were treated with CT-guided PRF. Of the 117 patients, 96 (82.1%) received immediate pain relief from the procedure, with 37 of them rating their pain as a 0/10 and 59 reporting their pain as a 1-3/10. The number of patients who got excellent pain relief was 75.9% at one year, 63.0% at 3 years, 54.0% at 5 years, 44.2% at 10 years, and 39.3% at 12.5 years (14).

A case report by Zhu, et al (30) reported 2 patients who suddenly developed GPN. The 47-year-old and 62-year-old women were both treated with CRF at 60°C for 60 seconds and 80°C for 120 seconds. The first patient had a pretreatment pain score of 8-10/10;post-treatment, she experienced complete pain resolution (30). It is important to note that this patient originally received PRF at 42°C, but her pain did not resolve, leading her to receive CRF instead. The second patient also experienced pain reduction with CRF. However, it is important to note that both patients experienced post-treatment tongue numbness, which eventually went away after 2-3 months (30).

An observational study by Telischak, et al (31) re-

ported on 18 patients. Fifteen had atypical facial pain (AFP), 2 had trigeminal neuralgia, and one had GPN. Two of the 15 patients with AFP had atypical GPN. For our study, we only examined the 2 patients with atypical GPN and one patient with typical GPN. Of the 2 patients with atypical GPN, only one experienced pain relief (31). This patient had an initial NRS-11 score of 5-6/10, which dropped to 0/10 immediately after the procedure. This yields an RFA efficacy of 2 out of 3 (66.7%) for the patients with GPN. Furthermore, 2 out of the 3 patients with GPN experienced postprocedure numbness to their throats, which eventually resolved (31).

Arbit, et al (32) reported a 87-year-old woman who lost 24 pounds after an unknown onset of GPN. Her episodes of severe paroxysmal pain were worsened during eating. A CT-guided RFA was performed and she experienced zero postprocedure pain(32).

Arias, et al (33) demonstrated the successful use of percutaneous RFA on a 58-year-old man and a 63-year-old man. Both experienced severe pain in their left pharynx that had also radiated to their external ear canals. After treatment, both patients experienced no pain and had no neurological complications (33).

Limitations

Although our systematic literature review demonstrates the high effectiveness of using RFA for treating patients with GPN, there are some limitations to consider. First, only 2 databases were employed in our study: PubMed and EMBASE. Although they are some of the most comprehensive and thorough databases available, there is a possibility that we missed articles not indexed in PubMed or EMBASE. Our initial systematic search yielded a total of 1,580 articles; after thorough screening by 3 reviewers, 18 articles were included in our study. One area of improvement may include the use of more databases that would allow us to review more observational studies, clinical trials, case series, and case reports. However, there have not been many studies that evaluate the using RFA for treating GPN, and to our knowledge, our systematic review evaluated most of the current articles available in the literature.

Furthermore, although we briefly mentioned the settings of the RFA used, such as its frequency and temperature, we were not able to do this for all of the articles analyzed. These inconsistencies may have affected the overall efficacy of RFA in treating GPN patients since the number of cycles, time/duration, power output, frequency, temperature, use of imaging guidance, and more can affect the success rate of the procedure. Some patients even received RFA treatment more than one time. Whether the RFA is pulsed or continuous may affect patient outcomes as well.

Our study also demonstrated that RFA may cause some negative complications for patients with GPN undergoing this procedure. Wang, et al (6) also observed patients who developed dysphagia, dysesthesia to their tongues, and developed a diminished gag reflex following treatment. In this study, 18 out of 80 patients (22.5%) experienced one of these symptoms (6). Salar, et al (23) observed that 6 out of 8 (75%) patients experienced hypotension and bradycardia following the operations. Interruptions to the vagus nerve were seen in 75% of the patients as well (23). Ori, et al (24) reported patients who developed more severe symptoms, such as seizures, bradycardia, and cardiac dysrhythmias in 6 out of 11 RFA procedures (54.5%). Zhu, et al (30) reported that 2 patients who underwent PRF treatment experienced numbness to their tongues that lasted for a few months. Other complications that patients may experience include damage to their nerves, infection, burns, and hemorrhage (38-40). One study that completed a follow-up on patients who had RFA treatment for trigeminal neuralgia found that out of 1,600 patients, 5.7% had a decreased reflex to their cornea, 4.1% experienced flaccidity to the masseter, 1% experienced dysesthesia, 0.8% experienced temporary paralysis to the third and sixth cranial nerves, and more (41). It is important to discuss risk and benefits to patients about the use of RFA; however, RFA has a long track record of being safe and effective for treating GPN and other diseases, as demonstrated in our systematic review.

Our systematic review may be limited by publication bias as well. It is possible that only studies with significant outcomes, either positive or negative, on using RFA for patients with GPN are the only ones published, whereas those with no significant results would not be published. Furthermore, our study mainly included case reports, case series, and observational studies; we only included one prospective interventional clinical trial. The absence of randomized clinical trials may lead our data to be more skewed or biased.

For the future, we may investigate and compare the efficacy of different types of RFA as well as the various settings of RFA for treating GPN. For example, we may compare using PRF with water-cooled CRF, or with cryo-

neurolysis in treating facial neuropathic pain (10). We could investigate other procedures or techniques that may or may not be more efficacious than RFA as well, such as nerve stimulation or cryoablation. Another area that we can focus on in the future is studying if there are any differences in patient outcomes when ablating specific branches of the glossopharyngeal nerve. This may allow us to identify the best approaches for treating GPN. Our systematic review revolved around qualitative studies; future works may include the addition of a meta-analysis to our study.

Conclusion

In conclusion, RFA has a clear role in managing facial pain due to GPN. In our study 80.2% of patients experienced pain relief, with the majority of these patients experiencing immediate pain relief post-RFA. One limitation of this study is the lack of clinical trials and controlled studies. Further research is needed to establish the long-term benefits and safety of RFA in managing GPN. Areas for future investigation include investigating the efficacy of different types of RFA in patients with GPN.

References

1. Han A, Montgomery C, Zamora A, et al. Glossopharyngeal Neuralgia: Epidemiology, Risk factors, Pathophysiology, Differential diagnosis, and Treatment Options. *Health Psychol Res* 2022; 10:36042.
2. Shah RJ, Padalia D. Glossopharyngeal neuralgia. In: *StatPearls [Internet]*. Treasure Island, FL: StatPearls Publishing; 2023. www.ncbi.nlm.nih.gov/books/NBK541041
3. Khan MZ, Iqbal MS, Ditta A. Management of refractory secondary glossopharyngeal neuralgia with percutaneous radiofrequency thermocoagulation. *Anaesthesia, Pain & Intensive Care* 2010; 14.
4. Gaul C, Hastreiter P, Duncker A, Naraghi R. Diagnosis and neurosurgical treatment of glossopharyngeal neuralgia: Clinical findings and 3-D visualization of neurovascular compression in 19 consecutive patients. *J Headache Pain* 2011; 12:527-534.
5. Singh PM, Kaur M, Trikha A. An uncommonly common: Glossopharyngeal neuralgia. *Ann Indian Acad Neurol* 2013; 16:1-8.
6. Wang X, Tang Y, Zeng Y, Ni J. Long-term outcomes of percutaneous radiofrequency thermocoagulation for glossopharyngeal neuralgia: A retrospective observational study. *Medicine (Baltimore)* 2016; 95:e5530.
7. Liu JF, Shen W, Huang D, et al. Expert consensus of Chinese Association for the Study of Pain on the radiofrequency therapy technology in the Department of Pain. *World J Clin Cases* 2021; 9:2123-2135.
8. Trescot AM. Cryoanalgesia in Interventional Pain Management. *Pain Physician* 2003; 6:345-360.
9. Eskandar E, Kumar H, Boini A, et al. The role of radiofrequency ablation in the treatment of trigeminal neuralgia: A narrative review. *Cureus* 2023; 15:e36193.
10. Wray JK, Dixon B, Przkora R. Radiofrequency Ablation. In: *StatPearls [Internet]*. Treasure Island, FL: StatPearls Publishing; 2023. www.ncbi.nlm.nih.gov/books/NBK482387
11. Wu H, Zhou J, Chen J, Gu Y, Shi L, Ni H. Therapeutic efficacy and safety of radiofrequency ablation for the treatment of trigeminal neuralgia: A systematic review and meta-analysis. *J Pain Res* 2019; 12:423-441.
12. Jena BR, Paswan A, Singh Y, Loha S, Singh AP, Rastogi V. A comparative study of continuous versus pulsed radiofrequency discectomy for management of low backache: Prospective randomized, double-blind study. *Anesth Essays Res* 2016; 10:602-606.
13. Jia Y, Shrestha N, Wang X, Wang T, Luo F. The long-term outcome of CT-guided pulsed radiofrequency in the treatment of idiopathic glossopharyngeal neuralgia: A retrospective multi-center case series. *J Pain Res* 2020; 13:2093-2102.
14. Song L, He L, Pei Q, et al. CT-guided percutaneous radiofrequency thermocoagulation for glossopharyngeal neuralgia: A retrospective clinical study of 117 cases. *Clin Neurol Neurosurg* 2019; 178:42-45.
15. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* 2021; 372:n71.
16. National Institutes of Health. National Heart, Lung, and Blood Institute. *Study quality assessment tools*. www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools
17. Martin J. Critical appraisal checklist for case reports. *Joanna Briggs Institute*, 2017. jbi.global/sites/default/files/2020-08/Checklist_for_Case_Reports.pdf
18. Nugent SM, Lovejoy TI, Shull S, Dobscha SK, Morasco BJ. Associations of pain numeric rating scale scores collected during usual care with research administered patient reported pain outcomes. *Pain Med* 2021; 22:2235-2241.
19. Atisook R, Euasobhon P, Saengsanon A, Jensen MP. Validity and utility of four pain intensity measures for use in international research. *J Pain Res* 2021; 14:1129-1139.
20. Swain BP, Vidhya S, Kumar S. Eagle's syndrome managed successfully by pulsed radiofrequency treatment. *Cureus* 2020; 12:e10574.
21. Mollinedo FT, Esteban SLT, Vega CG, Orcasitas AC, Maguregi AA. Pulsed radiofrequency treatment in a case of Eagle's syndrome. *Pain Pract* 2013; 13:399-404.
22. Bharti N, Chattopadhyay S, Singla N, Bala I, Batra YK, Bakshi J. Pulsed radiofrequency ablation for the treatment of glossopharyngeal neuralgia secondary to oropharyngeal carcinoma. *Pain Physician* 2018; 21:295-302.
23. Salar G, Ori C, Baratto V, Iob I, Mingrino S. Selective percutaneous thermolesions of the ninth cranial nerve by lateral cervical approach: Report of eight cases. *Surg Neurol* 1983; 20:276-279.

24. Ori C, Salar G, Giron GP. Cardiovascular and cerebral complications during glossopharyngeal nerve thermocoagulation. Anaesthesia 1985; 40:433-437.
25. van Tilburg CWJ. Percutaneous pulsed radiofrequency treatment in a patient with chronic bilateral painful glossopharyngeal neuropathy. *Am J Case Rep* 2020; 21:e920579-1-e920579-5.
26. Shah RV, Racz GB. Pulsed mode radiofrequency lesioning to treat chronic post-tonsillectomy pain (secondary glossopharyngeal neuralgia). *Pain Pract* 2003; 3:232-237.
27. Aggarwal A, Suresh V. Radiofrequency ablation and phenol neurolysis in a case of glossopharyngeal neuralgia due to a rare aetiology. *Indian J Anaesth* 2020; 64:437-439.
28. Salar G, Iob I, Ori C. Combined thermocoagulation of the 5th and 9th cranial nerves for oral pain of neoplastic aetiology. *J Maxillofac Surg* 1986; 14:1-4.
29. Chua NHL, Beems T, Vissers KC. Two cases of glossopharyngeal neuralgia successfully treated with pulsed radiofrequency treatment. *Ann Acad Med Singap* 2011; 40:387-389.
30. Zhu Q, Wang S, Chen R, et al. Continuous radiofrequency thermocoagulation under CT-guidance for glossopharyngeal neuralgia: Two case reports. *Medicine (Baltimore)* 2018; 97:e11079.
31. Telischak NA, Heit JJ, Campos LW, Choudhri OA, Do HM, Qian X. Fluoroscopic C-arm and CT-guided selective radiofrequency ablation for trigeminal and glossopharyngeal facial pain syndromes. *Pain Med* 2018; 19:130-141.
32. Arbit E, Krol G. Percutaneous radiofrequency neurolysis guided by computed tomography for the treatment of glossopharyngeal neuralgia. *Neurosurgery* 1991; 29:580-582.
33. Arias MJ. Percutaneous radiofrequency thermocoagulation with low temperature in the treatment of essential glossopharyngeal neuralgia. *Surg Neurol* 1986; 25:94-96.
34. Lee BB, Yu SP. Radiofrequency ablation of uterine fibroids: A review. *Curr Obstet Gynecol Rep* 2016; 5:318-324.
35. Leggett LE, Soril LJ, Lorenzetti DL, et al. Radiofrequency ablation for chronic low back pain: A systematic review of randomized controlled trials. *Pain Res Manag* 2014; 19:e146-e153.
36. Murali N, Turmezei T, Bhatti S, Patel P, Marshall T, Smith T. What is the effectiveness of radiofrequency ablation in the management of patients with spinal metastases? A systematic review and meta-analysis. *J Orthop Surg* 2021; 16:659.
37. Künzli BM, Abitabile P, Maurer CA. Radiofrequency ablation of liver tumors: Actual limitations and potential solutions in the future. *World J Hepatol* 2011; 3:8-14.
38. Huffman SD, Huffman NP, Lewandowski RJ, Brown DB. Radiofrequency ablation complicated by skin burn. *Semin Interv Radiol* 2011; 28:179-182.
39. Carrafiello G, Laganà D, Ianniello A, et al. Bleeding after percutaneous radiofrequency ablation: Successful treatment with transcatheter embolization. *Eur J Radiol* 2007; 61:351-355.
40. Nakagomi R, Tateishi R, Mikami S, et al. Infectious complications related to radiofrequency ablation of liver tumors: The role of antibiotics. *PLoS One* 2021; 16:e0259641.
41. Emril DR, Ho KY. Treatment of trigeminal neuralgia: Role of radiofrequency ablation. *J Pain Res* 2010; 3:249-254.