RESEARCH ARTICLE

DOI: 10.5935/0946-5448.20230040

International Tinnitus Journal. 2023;27(2):259-263

# Pulsed Radiofrequency of the Auriculotemporal Nerve to Reduce the Intensity of Tinnitus

Henk M. Koning *

## ABSTRACT

**Introduction:** Stimulation of the nonauditory nervous systems via the trigeminal nerve pathways can be a promising intervention for patients with tinnitus refractory to medical, conservative, and other treatment options. Therapy of the mandibular division of the trigeminal nerve through the auriculotemporal nerve has been reported as useful for patients with tinnitus.

**Objectives:** The objective of our study was to study the long-term effects of pulsed radiofrequency of the auriculotemporal nerve in a large group of tinnitus sufferers and to find predictors for a prosperous result.

**Design:** A monocenter backward-looking group study.

**Results:** In a two-year period, 67 tinnitus patients had pulsed radiofrequency of the auriculotemporal nerve. Twenty-three (35%) reported reduced tinnitus loudness at the 7-week post-treatment follow-up. These patients valued the improvements as: 61% good, 22% moderate, and 17% slight. In 3% of patients, tinnitus magnified after the treatment. The odds of permanent tinnitus relief after successful pulsed radiofrequency of the auriculotemporal nerve are 68% at 1 year postoperative. In tinnitus patients without cervical pain 62% had an improvement following pulsed radiofrequency of the auriculotemporal nerve compared to 28% in those not fulfilling this criterion ($p=0.024$).

**Conclusions:** Neuromodulation of the auriculotemporal nerve is an uncomplicated remedy for tinnitus. In a select group of tinnitus patients this treatment can a good relief of their tinnitus for a long period. Especially, tinnitus sufferers without cervical pain will benefit of this therapy

**Keywords:** Tinnitus, Auriculotemporal Nerve, Trigeminal Nerve, Pulsed Radiofrequency, Cervical Pain.

Department of Pain therapy, Pain Clinic De Bilt, De Bilt, The Netherlands

***Send correspondence to**
H.M. Koning
Department of Pain therapy, Pain Clinic De Bilt, De Bilt, The Netherlands, Tel: 0031302040753, E-mail: hmkoning@pijnkliniekdebilt.nl

Paper submitted on December 31, 2023; and Accepted on January 20, 2023

## INTRODUCTION

Tinnitus is the awareness of noise unaccompanied by an external cause. Convergence of the auditory with somatosensory systems in the brainstem is the subject of extensive studies for the commencement of tinnitus [1-4]. In the Cochlear Nucleus (CN) auditory information mixes with information coming from somatosensory nuclei, which include the trigeminal nervous system. Disruptions in both systems may cause tinnitus [5].

Stimulation of the nonauditory nervous systems via the Trigeminal Nerve (TN) can be a promising intervention for patients suffering from tinnitus refractory to medical, conservative, and other treatment options. Therapy of the Auriculotemporal Nerve (AN) has proven useful for patients suffering from tinnitus [6]. However, electrical stimulation of this nerve is not documented as potential treatment for reducing subjective tinnitus. Especially, Pulsed Radio Frequency (PRF) has already been used in therapy of tinnitus with few adverse effects [7]. Therefore, the intention of this inquiry is to check this treatment on a group of tinnitus patients, estimate the long-term effect of PRF of the AN, and find clinical predictors for a successful result.

## METHODS

### Design

A monocenter retrospective study in Pain Clinic De Bilt, De Bilt, the Netherlands.

### Ethical approval

The Ethics Committee United (Nieuwegein, the Netherlands) permitted this study (W23.208, October 12, 2023). Each patient gave informed permission to the treatment.

### Subjects

This study includes all tinnitus patients who underwent PRF of the AN in Pain Clinic De Bilt between January 2022 and October 2023 (n = 67). Other therapy options offered were counseling by a neurologist or ENT-specialist, medication advice, and therapy of ganglion C2 or ganglion cervical superior; outcomes of these therapies are not analyzed here. No further rejection criteria for PRF of the AN were used. Before therapy, each patient filled in a questionnaire and qualified the loudness of tinnitus on a visual analogue scale (0 – 100 mm). Furthermore, a two-sided audiogram and a radiograph of the cervical spine was acquired before the treatment started.

### Outcome

The prime outcomes were subjective change in tinnitus loudness at 7 weeks post treatment and time of sustained tinnitus relief following therapy.

### Adverse effects

Side effects were registered directly after and at 7 weeks post treatment.

### Hearing assessment

A two-sided audiogram for the tone thresholds from 250 to 8000 Hz (in dB HL).

### Radiograph of the neck

Measurements of the radiographs of the cervical spine are exemplified in Figure 1.

### Pulsed radiofrequency of the auriculotemporal nerve

The treatment was executed by an anesthesiologist. After decontamination, a 22-gauge, 60 mm-long needle with a 5 mm active tip was put in about 6 millimeters in front of the joining of the tragus and the earlobe, posteriorly to the mandible. The needle is advanced superior into the sub condylar area to a depth of about 25-28 millimeter. Then PRF at 42 V, 2 Hz, and 10 milliseconds for 10 minutes was applied. Postoperative, patients were monitored for half an hour. Patients were re-evaluated 7 weeks post treatment. Treatment was directed to the side(s) where the tinnitus was the loudest.

### Data Assessment

Obtained information included tinnitus features from the clinical questionnaire (dominant side of tinnitus, period of tinnitus, presence of diminished hearing, dizziness or balance disorders), self-reported profit at seven weeks post treatment on a four-point scale (none [0%], slight [< 25%], moderate [25% -50%], good [50% or greater]), and the duration of action. Seven weeks postoperative, further therapy was offered. When another therapy was received, the improvement until the last therapy was documented and added in the survival analysis as period of ongoing tinnitus relief. Patients with a beneficial PRF of the AN and no recurrence nor other therapy, were invited for a question-and-answer session to value duration of improvement. In December 2023, a survey by an unprejudiced observer was accomplished.

### Statistical Methods

Data were looked into with Minitab 18 (Minitab Inc., State College, PA, USA) using Student's t-test, $\chi 2$ test, and survival analysis. Discriminant analysis get the measure how variables correlate to the outturn of PRF of the AN. A P-value less than 0.05 stipulated statistically meaningful.

## RESULTS

In a two-year period, 67 tinnitus patients underwent PRF of the AN. Table 1 presents the clinical hallmarks. Twenty-three (35%) reported reduced tinnitus loudness at the 7-week post-treatment follow-up. These patients valued the improvements as: 61% good, 22% moderate, and 17% slight. Tinnitus magnified in 3% of the patients following the PRF of the AN. Patients were perceived for up to 14 months postoperative. The odds of permanent tinnitus relief after successful PRF of the AN are 68% at 1 year postoperative (Figure 2).

Patients with a beneficial result of PRF of the AN were set side by side to tinnitus sufferers with no effect after this treatment (Table 2). Only the appearance of cervical pain

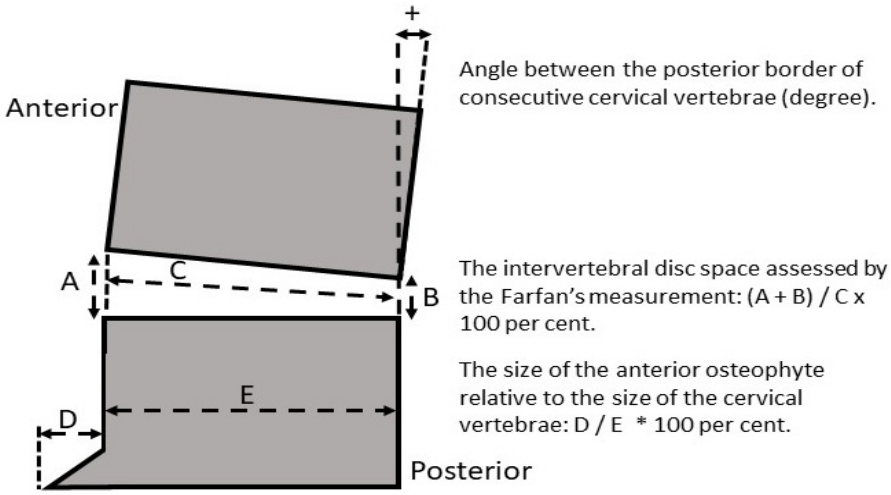


**Figure 1:** Measurements of the radiographs of the cervical spine.

**Table 1:** Clinical characteristics of the patients with tinnitus.

| | Prevalence | Median | Q1 – Q3 |
|---|---|---|---|
| Age (year) | | 54 | 44 – 63 |
| Gender (male) | 61% | | |
| Unilateral tinnitus | 34% | | |
| Self-perceived hearing loss | 67% | | |
| Cervical pain | 80% | | |
| Period of tinnitus (year) | | 5 | 2 – 15 |
| Perceived intensity of tinnitus (mm) | | | |
| Mean | | 69 | 49 – 84 |
| Minimal | | 30 | 24 – 63 |
| Maximal | | 84 | 75 – 94 |
| Hearing loss (dB) at: | | | |
| 250 Hz | | 15 | 10 – 36 |
| 500 Hz | | 15 | 10 – 38 |
| 1 kHz | | 15 | 10 – 38 |
| 2 kHz | | 20 | 10 – 45 |
| 4 kHz | | 30 | 20 – 60 |
| 8 kHz | | 45 | 20 – 70 |

Q1 – Q3: Inter-Quartile Range.

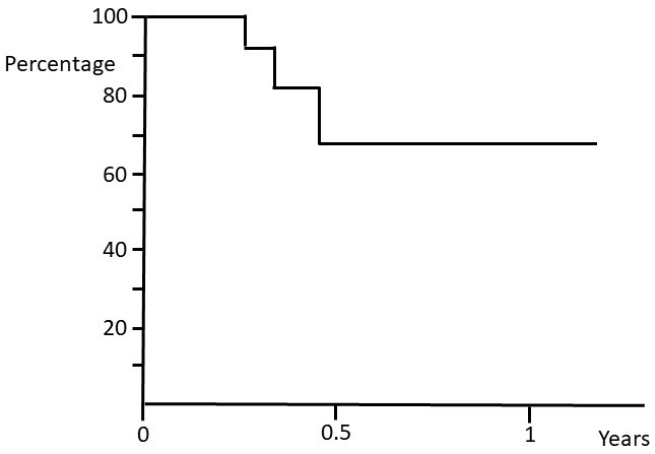


**Figure 2:** Kaplan-Meier graph to show indicating the odds of permanent tinnitus relief in successfully treated patients (n=20) after PRF of the auriculotemporal nerve. Three patients did not respond to our invitation for a question-and-answer session to value time of improvement.

**Table 2:** Patients with a positive effect of therapy of the auriculotemporal nerve on their tinnitus at 7 weeks were compared with non-responders.

| | Positive effect of therapy (n=23) | | | No effect of therapy (n=43) | | | P-value | |
|---|---|---|---|---|---|---|---|---|
| | Prev. | Mean | SEM | Prev. | Mean | SEM | | |
| Age (year) | | 55 | 2.8 | | 57 | 1.7 | 0.865 | |
| Gender (male) | 65% | | | 60% | | | 0.705 | |
| Unilateral tinnitus | 39% | | | 33% | | | 0.595 | |
| Self-perceived hearing loss | 70% | | | 65% | | | 0.715 | |
| Cervical pain | 65% | | | 88% | | | 0.024 | Sign. |
| Age at the start of tinnitus (year) | | 46 | 3.8 | | 44 | 2.4 | 0.613 | |
| Hearing loss (dB) at: | | | | | | | | |
| 250 Hz | | 26 | 4.7 | | 21 | 3.1 | 0.357 | |
| 500 Hz | | 30 | 5.4 | | 21 | 2.9 | 0.148 | |
| 1 KHz | | 29 | 5.2 | | 23 | 3.2 | 0.339 | |
| 2 KHz | | 33 | 5.4 | | 26 | 3.1 | 0.232 | |
| 4 KHz | | 45 | 5.6 | | 38 | 3.7 | 0.279 | |
| 8 KHz | | 50 | 6.3 | | 44 | 4.4 | 0.492 | |
| Angle between vertebrae C2 and C6 (degrees): | | 6 | 2.1 | | 7 | 1.6 | 0.779 | |
| Farfan's measurement of disc space height (%): | | | | | | | | |
| C2-C3 | | 41 | 1.6 | | 40 | 1.3 | 0.637 | |
| C3-C4 | | 35 | 2.1 | | 36 | 1.3 | 0.693 | |
| C4-C5 | | 35 | 1.8 | | 35 | 1.4 | 0.995 | |
| C5-C6 | | 26 | 1.8 | | 28 | 1.4 | 0.369 | |
| C6-C7 | | 26 | 1.7 | | 26 | 1.6 | 0.925 | |
| Size of anterior osteophyte (%) at: | | | | | | | | |
| C3 | | 7 | 0.9 | | 10 | 0.9 | 0.055 | |
| C4 | | 13 | 1.3 | | 12 | 1.0 | 0.724 | |
| C5 | | 20 | 2.1 | | 18 | 1.1 | 0.475 | |
| C6 | | 15 | 1.5 | | 14 | 1.1 | 0.643 | |

dB: decibel; Hz: Hertz; KHz: Kilohertz; SEM: Standard Error of the Mean; Sign: Significant; Prev.: Prevalence.

in tinnitus patients was statistically significant. In tinnitus patients without cervical pain 62% had an improvement following PRF of the AN compared to 28% in those not fulfilling this criterion (p=0.024).

## DISCUSSION

In a cohort of patients with tinnitus, 35% of the patients responded with a reduction of their tinnitus after a PRF of the AN. Most of the patients (61%) with a positive response rated the effect of therapy as a reduction of 50% or more. At 1 year postoperative, 68% of the initially successful treated patients still experienced a benefit. Adverse events of the PRF of the AN at 7 weeks of follow-up were minor: 3% of the patients report a louder tinnitus.

The CN is the first site of multisensory blending in the auditory nervous system [4]. It mixes auditory inputs with information from somatosensory nuclei, which includes the Spinal Trigeminal Nucleus (STN) [8]. Feelings from the head, neck, and face are transferred by the TN to the brainstem trigeminal sensory complex including the STN [9]. The STN receives nociceptive and proprioceptive information from the head, face, oral structures, the temporo-mandibular joint, and cervical spine (C1–C3) [10]. Nociceptive stimuli from the facial, glossopharyngeal and vagal nerves also goes to the STN [11]. The STN projects extensively to the CN [12]. The neural pathway from the STN to the CN ends mostly as mossy fibers on granule cells in the granule cell domain [4,9-10]. The granule cells synapse with the fusiform cells, the main exit of the Dorsal Cochlear Nucleus (DCN). Somatosensory inputs also contact bushy cells and D-stellate cells in the Ventral Cochlear Nucleus (VCN). Bushy cells project to sound localization centres in the superior olivary complex. The axons of the trigeminal ganglion contact the cells in VCN, and can directly modify CN output [10].

A loud noise heard in one ear causes a reflex which contracts the tensor tympani and stapedius muscles of both ears [2]. The afferent of this reflex is directed by activity of nerve fibers in the cochlea and propels the efferent response via the facial and auriculotemporal nerves. The trigeminal nuclei control the ear muscle reflex.

Tinnitus is the awareness of noise unaccompanied by an external cause. The originating of tinnitus is complex and this complies also for the influence of the TN [2]. The TN can act on the stria vascularis or on CN neurons. The TN innervates the vascular system around the spiral modiolus and the stria vascularis. The stria vascularis regulates the composition of the endolymph which is vital for sound transduction. Malfunction of the stria vascularis impairs hearing and can cause tinnitus. Tinnitus can also be linked with a disinhibition of the DCN, due to CN receiving excitation from inner hair cells and no inhibition

from damaged outer hair cells, consequently causing hyperactivity within the auditory system [13]. Damage to outer hair cells could preferentially affect those pyramidal cells with somatosensory inputs via the granule cell - parallel fiber system [9].

Neuromodulator of the ophthalmic or the mandibular divisions of the TN can lower the loudness of tinnitus [10,12]. This method produces neuronal excitation in the VCN and a combination of excitation and inhibition in the DCN [4,14]. The localization and response characteristics correspond with fusiform cells in the DCN and the bushy and stellate cells in the VCN [1]. Moreover, these neurons are also the neurons showing enhanced spontaneous activity following hearing loss [2]. Hearing loss increases the excitatory effects of TN stimulation [2]. Also, we found raised hearing thresholds in the tinnitus group with a beneficial effect of PRF of the AN. Stimulation of the TN can also, via the rostral ventrolateral medulla (RVLM) and trigemino-cerebrovascular system, increase the cerebral perfusion [15].

We use PRF of the AN as method for TN stimulation. PRF has already been used as therapy of tinnitus with few adverse effects [7]. PRF of the AN had a good and long-lasting effect in a select group of tinnitus sufferers with few side-effects. We recommend this therapy especially in tinnitus patients without cervical pain. The lowering of the loudness of tinnitus caused by PRF of the AN is most likely due to its action on the fusiform cells of the DCN or on the bushy and stellate cells of the VCN.

The statements in this study are constrained owing to its backward-looking quality and the restricted number of patients involved. A prospective investigation, including a placebo-controlled double-blinded approach, with more patients can affirm the outcome and our interpretations.

## CONCLUSION

PRF of the AN is an uncomplicated remedy option for lowering tinnitus loudness. In a select group of tinnitus sufferers this treatment can offer a good and long-lasting beneficial result with few side-effects. It is hard to assess beforehand which patient will benefit of this therapy. Especially, tinnitus sufferers without cervical pain will benefit of this therapy.

## REFERENCES


1. Ralli M, Greco A, Turchetta R, Altissimi G, de Vincentiis M, Cianfrone G. Somatosensory tinnitus: Current evidence and future perspectives. J Int Med Res. 2017;45(3):933-47.
2. Norena AJ, Fournier P, Londero A, Ponsot D, Charpentier N. An integrative model accounting for the symptom cluster triggered after an acoustic shock. Trends Hear. 2018;22:2331216518801725.
3. Cheng YF, Xirasagar S, Yang TH, Wu CS, Kao YW, Shia BC, etal. Increased risk of tinnitus following a trigeminal neuralgia diagnosis: A one-year follow-up study. J Headache Pain. 2020;21(1):1-7.
4. Balmer TS, Trussell LO. Trigeminal Contributions to the Dorsal Cochlear Nucleus in Mouse. Front Neurosci. 2021;15:715954.
5. Tzounopoulos T, Balaban C, Zitelli L, Palmer C. Towards a mechanistic-driven precision medicine approach for tinnitus. J Assoc Res Otolaryngol. 2019;20(2):115-131.
6. Sirh SJ, Sirh SW, Mun HY, Sirh HM. Integrative treatment for tinnitus combining repeated facial and auriculotemporal nerve blocks with stimulation of auditory and non-auditory nerves. Front Neurosci. 202;16:758575.
7. Koning HM, Heeringa AN. Pulsed Radiofrequency of the Auricular Branch of the Vagal Nerve in Tinnitus Patients. Int Tinnitus J. 2023;27(1):68-74.
8. Wu C, Stefanescu RA, Martel DT, Shore SE. Tinnitus: maladaptive auditory–somatosensory plasticity. Hear Res. 2016;334:20-9.
9. Shore SE, Koehler S, Oldakowski M, Hughes LF, Syed S. Dorsal cochlear nucleus responses to somatosensory stimulation are enhanced after noise-induced hearing loss. Eur J Neurosci. 2008;27(1):155-68.
10. Dehmel S, Cui YL, Shore SE. Cross-modal interactions of auditory and somatic inputs in the brainstem and midbrain and their imbalance in tinnitus and deafness. Am J Audiol. 2008;17(2):S193-209.
11. Bičanić I, Hladnik A, Džaja D, Petanjek Z. The anatomy of orofacial innervation. Acta Clin Croat. 2019;58(Suppl 1):35-42.
12. Boedts MJ. Tympanic resonance hypothesis. Front Neurol. 2020;11:14.
13. Omidvar S, Jafari Z, Mahmoudian S, Khabazkhoob M, Ahadi M, Yazdani N. The relationship between ultra-high frequency thresholds and transient evoked otoacoustic emissions in adults with tinnitus. Med J Islam Repub Iran. 2016;30:449.
14. Soleymani T, Pieton D, Pezeshkian P, Miller P, Gorgulho AA, Pouratian N, etal. Surgical approaches to tinnitus treatment: A review and novel approaches. Surg Neurol Int. 2011;2:154.
15. White TG, Powell K, Shah KA, Woo HH, Narayan RK, Li C. Trigeminal nerve control of cerebral blood flow: a brief review. Front Neurosci. 2021;15:649910.