

The eight cervical nerve and its role in tinnitus

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ABSTRACT

Introduction: The eight cervical nerve might be a source of input to the auditory system.

Objectives: The object was to assess the efficacy of infiltration of the eight cervical nerve root for treating tinnitus patients and to find indicators for a successful result.

Design: Retrospective cohort study. Subjects were 79 tinnitus patients visiting our clinic in a three-year period and who were treated with infiltration of the eight cervical nerve root.

Results: Twenty-six percent of the tinnitus patients had a reduction of their tinnitus following an infiltration of the eight cervical nerve root. Most of the successfully treated patients rated the effect of therapy as a moderate reduction of 25% to 50%. Fifty percent of the successful treated patients still had benefit at 6.6 months. In 5% of the patients, their tinnitus was aggravated after the infiltration of the eight cervical nerve roots. Patients with a hearing loss at 500 Hz that exceed the hearing loss at 2 kHz responded the most to infiltration of the eight cervical nerve.

Conclusion: Infiltration of the eight cervical nerve root reduced the intensity of tinnitus in 26% of the cohort of 79 tinnitus patients with a moderate to good effect. This therapy for tinnitus patients' needs to be considered, especially in those with a hearing loss at 500 Hz that exceed the hearing loss at 2 kHz.

Keywords: Tinnitus; nerve root infiltration; dorsal cochlear nucleus; cervical spine; eight cervical nerve ; cuneate nucleus.

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INTRODUCTION

The somatosensory system innervating the head, neck, and shoulders is closely associated with the auditory system¹⁻⁴. Neurons that link to the auditory pathway reside in the dorsal root ganglia of the second, the seventh, and the eight cervical nerve and in the trigeminal ganglion⁵. Treatment of the second cervical nerve can result in a reduction of the intensity of tinnitus for a subgroup of tinnitus patients⁶. However, there are no studies of therapy of the eight cervical nerve in tinnitus patients. The object was to assess the effect of infiltration of the eight cervical nerve root for treating tinnitus and to find indicators for a successful result.

MATERIALS AND METHODS

Design: A monocenter retrospective cohort study.

Ethical Approval: Approval was given by the Medical research Ethics Committees United (Nieuwegein, the Netherlands).

Subjects: Patients with tinnitus lasting longer than 1 month and referred to Pain Clinic De Bilt by their general practitioner or otolaryngologist. Additional inclusion criterium was a magnetic resonance imaging of the brain in patients with unilateral tinnitus. All patients treated with infiltration of the eight cervical nerve roots for tinnitus in our clinic in a three-year period (October 2016 - October 2019) were included.

Outcome: The primary outcomes were self-reported benefit at 7 weeks on a 4-point Likert scale (none [0%], slight [less than 25%], moderate [25% to 50%], good [50% or more]), and the period of relief.

Adverse Effects: Adverse events were recorded, whether or not caused by the procedure.

Infiltration of the Eight Cervical Nerve Root: All infiltrations of the eight cervical nerve were performed on an outpatient basis. The patient was in supine position during the procedure. The radiographic projection was in oblique view with the neural foramen of the eight cervical nerve at its largest diameter. This level was marked with a pointer on the skin and used as entry point for the needle. The puncture site was disinfected and a 23-gauge needle (Top Neuropore needle XE-S, Tokyo, Japan) was introduced. Under X-ray guidance, the needle tip was placed at the opening of the foraminal canal of the eight cervical nerve. Under continuous fluoroscopic guidance, 0.5 ml Iohexol (Omnipaque 240, Eindhoven, the Netherlands) was injected. The contrast should be seen to flow around the nerve root but should not flow proximally into the epidural, subdural, or subarachnoid space. After confirming the needle position and without aspirating of blood, a mixture of 0.5 ml bupivacaine 0.5% (Bupivacaine Aurobindo, Baarn, the Netherlands) and 0.5 ml dexamethasone (Dexamethasone CF, Etten-Leur, the Netherlands) were injected. The patients were re-evaluated 7 weeks following therapy.

Data Assessment: The charts of all tinnitus patients were reviewed retrospectively to select those who underwent an infiltration of the eight cervical nerve for tinnitus. Data recorded from these patients included tinnitus characteristics, self-reported benefit at 7 weeks on a 4-point Likert scale (none [0%], slight [less than 25%], moderate [25% to 50%], good [50% or more]), and the duration of action. The findings of the audiogram at the worst side of the tinnitus were used for analysis. In case of tinnitus with equal intensity on both sides, the mean of the audiographic findings was used for analysis. The lateral cervical spine radiograph was used for measuring the parameters of the cervical vertebral column⁶. Seven weeks after the procedure, further therapy of tinnitus was continued. If patients underwent other treatments, the duration of action until the next treatment was recorded. All tinnitus patients with a good result following infiltration of the eight cervical nerve root and without relapse, were requested for an interview. In December 2019, an assessment by telephone took place to evaluate the time of recurrence of their tinnitus.

Statistical Methods: The data were statistical analysed with Minitab 18 (Minitab Inc., State College, PA, USA). For continuous and for dichotomous variables, Student's t-test and χ^2 test were calculated respectively. Survival analysis techniques computed the duration of the effect of therapy. Multiple regression analysis obtained a model to predict a successful result on tinnitus. Discriminant analysis evaluated the correlation of variables with the result of the infiltration of the eight cervical nerve root. A P-value less than 0.05 was statistically significant.

RESULTS

In a three-year period, 79 tinnitus patients underwent infiltration of the eight cervical nerve root. A description of this patient is shown in Table 1. There was three drop-outs. Twenty of seventy-six patients (26%) observed a reduction of their tinnitus afterwards and they rated the improvement as: 25% good, 55% moderate, and 20% slight. In 5% of the patients, their tinnitus was aggravated after the infiltration of the eight cervical nerve root. Figure 1 shows a Kaplan-Meier plot indicating the probability of permanent tinnitus relief after successful infiltration of the eight cervical nerve root. Fifty percent of the successful treated patients still had benefit at 6.6 months. Patients with a positive result of infiltration of the eight cervical nerve root on the tinnitus were compared with the other patients (Table 2). Reduced hearing at the lower frequencies (250-1000 Hz) was found in the group of patients with a positive outcome of infiltration of the eight cervical nerve root on tinnitus, however it was not statistical significant. Multivariate analysis indicated that reduced hearing at 500 Hz and at 2000 Hz predict successful outcome of infiltration of the eight cervical nerve root on tinnitus ($p=0.037$). With discriminant analysis, the patient group with a higher chance on positive result of infiltration of the eight cervical nerve root was identified (Figure 2). Patients fulfilling these criteria, 41% of them were successfully

Table 1: Clinical characteristics of the patients with tinnitus.

	Prevalence	Median	Q1 – Q3
Age (year)		60	52 – 67
Gender (male)	67%		
Unilateral tinnitus	39%		
Self-perceived hearing loss	71%		
Cervical pain	62%		
Period of tinnitus (year)		7.0	2.5 – 17.0
Hearing loss (dB) at:			
250 Hz		15	10 – 31
500 Hz		15	10 – 30
1 KHz		15	10 – 40
2 KHz		20	10 – 40
4 KHz		40	25 – 60
8 KHz		60	35 – 73

dB: decibel; Hz: Hertz; KHz: Kilohertz; Q1 – Q3: Inter-Quartile Range.

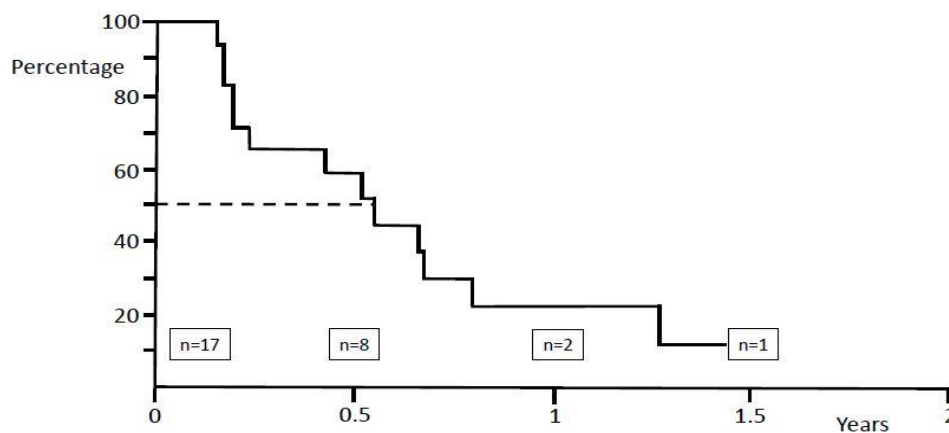


Figure 1: Kaplan-Meier plot to show probability of sustained tinnitus relief in successfully treated patients (n=17) after an infiltration of the eighth cervical nerve.

treated with infiltration of the eighth cervical nerve root. The criteria shown in Figure 2 had a sensitivity of 55% and a specificity of 71% for predicting a successful response following infiltration of the eighth cervical nerve root in patients with tinnitus. Positive and negative predictive values were 41% and 82% respectively.

DISCUSSION

Infiltration of the eighth cervical nerve root reduced the intensity of tinnitus in 26% of the cohort of 79 tinnitus patients with a moderate to good effect. 50% of the successful treated patients still had benefit at 6.6 months. Patients with a hearing loss at 500 Hz that exceed the hearing loss at 2 kHz responded the most to infiltration of the eighth cervical nerve.

Tinnitus can be related to the nervous system of the cervical spine². The cervical structures evoke inhibitory and excitatory responses in the dorsal cochlear nucleus with a predominance of inhibitory responses^{7,8}. Activation of the dorsal root ganglia can cause disinhibition of the dorsal cochlear nucleus eventually resulting in tinnitus⁹. The neurons that cross-connect to the auditory system are present in the dorsal root ganglia of the second, the seventh, and the eighth cervical nerve, and in the trigeminal ganglion¹⁻³. In our study, we observe an effect

of infiltration of the eighth cervical nerve root in 26% of the tinnitus patients, indicating that the eighth cervical nerve is involved in the pathogenesis of tinnitus.

The dorsal root ganglion is the origin of the dorsal column-medial lemniscal system (Figure 3). The dorsal column-medial lemniscal system mediates proprioception and discriminative sensation, and includes the cuneate nucleus. The dorsal root ganglia of the seventh and the eighth cervical nerves project to the cuneate nucleus¹⁰. The cuneate nucleus transmit their information to the granule cell domain of the cochlear nucleus⁴. The granule cell domain is a part of extralemniscal auditory pathway ending at the secondary auditory cortex¹. It can stimulate the central auditory system in a manner distinct from acoustic stimulation and it is linked to the limbic system. The extralemniscal auditory system is related to mechanisms underlying tinnitus

A disbalance between the auditory and the somatosensory input to the auditory pathway can elicit tinnitus¹¹. Reduced auditory input makes the dorsal cochlear nucleus more sensitive to trigeminal stimulation⁸. It seems that these findings could also be valid for input from the cervical dorsal root ganglia. In our study, a successful result of infiltration of the eighth cervical nerve root was associated

Table 2: Patients with a positive effect of therapy of the eight cervical nerves on their tinnitus at 7 weeks were compared with non-responders.

	Positive effect of therapy of nerve C8 (n=20)			No effect of therapy of nerve C8 (n=56)			P-value
	Prev.	Mean	SEM	Prev.	Mean	SEM	
Age (year)		58	2.3		60	1.7	0.619
Gender (male)	65%			68%			0.816
Unilateral tinnitus	40%			38%			0.844
Self-perceived hearing loss	75%			68%			0.546
Cervical pain	65%			64%			0.954
Age at the start of tinnitus (year)		49	2.4		48	2.0	0.794
Hearing loss (dB) at:							
250 Hz		31	5.8		21	2.7	0.153
500 Hz		32	5.8		22	2.9	0.129
1 KHz		32	5.8		22	2.9	0.145
2 KHz		30	5.0		27	3.2	0.608
4 KHz		43	4.7		45	3.4	0.701
8 KHz		56	6.5		57	3.8	0.887
Angle between vertebrae C2 and C6 (degrees):		9	2.0		8	1.4	0.652
Farfan's measurement of disc space height (%):							
C2-C3		39	1.9		39	1.1	0.872
C3-C4		36	1.3		35	1.3	0.582
C4-C5		33	2.0		34	1.1	0.645
C5-C6		27	2.1		25	1.2	0.386
C6-C7		24	2.0		26	1.1	0.435
Size of anterior osteophyte (%):							
C3		7	1.1		8	0.7	0.449
C4		10	1.2		12	1.0	0.477
C5		20	1.9		19	1.2	0.475
C6		14	1.4		14	0.9	0.966

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

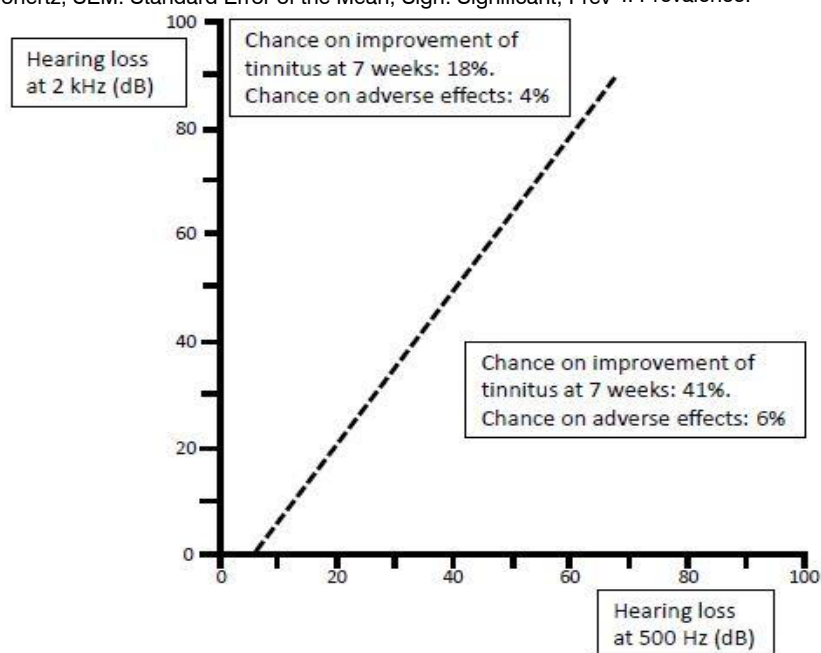


Figure 2: Hearing loss at 500 Hz and at 2000 Hz can predict a positive effect of temporomandibular steroids on tinnitus at 7 weeks follow-up (Proportion Correct=0.671). For instance, if a patient has 60 dB hearing loss at 500 Hz and 20 dB hearing loss at 2 kHz, there is a 41% chance of improvement with a 6% chance of adverse effects.

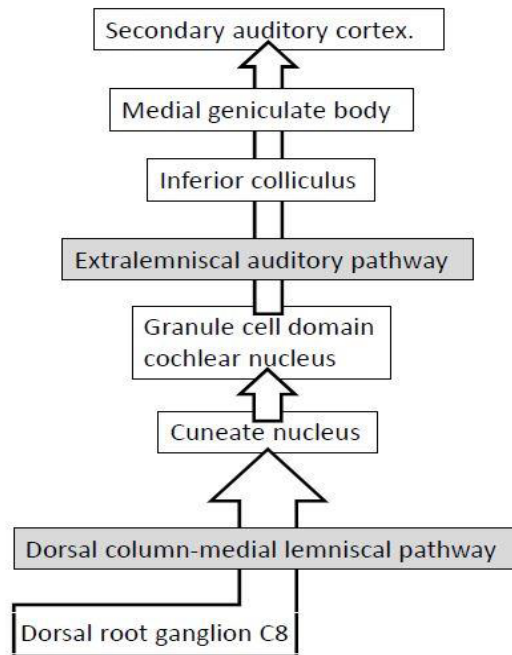


Figure 3: The way the dorsal root ganglion of the eight cervical nerves may induce tinnitus.

with a hearing loss at 500 Hz that exceed the hearing loss at 2000 Hz.

Cervical spine disorders can trigger tinnitus^{12,13}. Degenerative changes in the lower cervical spine are reported to only rarely cause tinnitus, while instability at the craniocervical junction or dysfunction between the second and the fourth cervical vertebrae more often results in tinnitus¹³. However, we found that in 26% of all tinnitus patients the eight cervical nerve is probably involved in the pathogenesis. Also, most of the tinnitus patients had disc degeneration between the fifth and the seventh cervical vertebrae in combination with an anterior osteophyte of the fifth cervical vertebrae. Statistical analysis of the effect of nerve infiltration of the eight cervical nerve did not show any significant difference for signs of degenerative changes of the cervical spine. It could be possible that we did not include the correct cervical level in our study. The intervertebral disc between the seventh cervical and the first thoracic vertebrae is difficult to assess on the lateral cervical spine radiograph of the cervical spine, because of the projections of the shoulders.

Limitations are the retrospective design, the outcome measures, and the number of patients in our study. A prospective study is recommended. Another limitation is the use of lateral cervical spine radiograph in this study. MRI might be a better choice for observing any pathology between the seventh cervical and the first thoracic vertebrae.

CONCLUSION

Modification of somatosensory input the auditory system can be useful for treating tinnitus patients. Infiltration of the eight cervical nerve root reduced the intensity of tinnitus in 26% of the cohort of 79 tinnitus patients with a

moderate to good effect. This therapy for tinnitus patients' needs to be considered, especially in those with a hearing loss at 500 Hz that exceed the hearing loss at 2 kHz.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest on publishing this paper.

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