REVIEW PAPER

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Hearing Loss at 250 Hz Can Differentiate Between Different Subtypes of Tinnitus: A Retrospective Chart Review

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Abstract

Introduction: Patients suffering from tinnitus are a heterogeneous group. Different subtypes may indicate a different pathogenesis. The subgroups need to be identified in order to find effective treatments.

Objectives: The aim of this study was to identify the characteristics of unilateral and bilateral tinnitus to differentiate between different subtypes, using history, audiograms and radiographs of the cervical spine.

Methods: A retrospective chart review of 95 consecutive patients with tinnitus that persisted for one month or longer was performed.

Results: Patients with unilateral tinnitus had a statistically significant lesser hearing from 250 Hz to 1 KHz compared to bilateral tinnitus. There were no statistically significant differences in radiographic measurements between both groups. Multivariate analysis indicated that hearing loss at 250 Hz was the strongest variable associated with the presence of uni-and bilateral tinnitus. In patients with tinnitus, a hearing loss of more than 23 decibels at 250 Hz was characterized by a high prevalence of self-perceived hearing loss (92% of the patients), balance disorders (75% of the patients), vertigo (63% of the patients), and unilateral tinnitus (54% of the patients).

Conclusion: Two subgroups of patients with tinnitus suggest two different pathogenesis: otogenic and non-otogenic tinnitus. Hearing loss at 250 Hz of more than 23 decibels could differentiate between the two forms. There was a higher prevalence of unilateral tinnitus in patients with otogenic tinnitus compared to patients with non-otogenic tinnitus.

Keywords: tinnitus, vertigo, audiograms, otogenic tinnitus.

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INTRODUCTION

Hearing loss is believed to trigger the perception of tinnitus in the central auditory system[1]. Nevertheless, also cervical pathology[2-4] and interactions between the somatosensory and auditory systems[5] play a role in the etiology of tinnitus. However, it is unknown which cervical pathology and which results of the audiogram are related to the occurrence of tinnitus.

Two types of tinnitus, depending on the amount of hearing loss, have been identified; an auditory related form not associated with hearing loss and a (para) hippocampal form associated with hearing loss[2]. Hearing loss is believed to trigger the perception of tinnitus in the central auditory system, because it causes a deprivation of input to the auditory nervous system and is considered to activate neural plasticity associated with tinnitus[1]. This type of tinnitus is called otogenic tinnitus. Another type of tinnitus, somatosensory tinnitus, is caused by somatic disorders involving the head and upper neck[3,4,6].

Studies have shown that bilateral tinnitus differs from unilateral tinnitus[7]. It is possible that uni or bilateral tinnitus represent different subtypes of tinnitus with other pathogenesis. Therefore, the aim of this study was to identify the characteristics of unilateral and bilateral tinnitus to differentiate between different subtypes, using history, audiograms and radiographs of the cervical spine.

METHODS

Subjects

The Medical Ethical Research Committee United (Nieuwegein, the Netherlands) approved the present observational study. No informed consent was required for the current study. A retrospective chart review was conducted. The human subjects were 95 consecutive patients who came to Pain Clinic De Bilt from October 2016 to October 2017 for consultations on their tinnitus that persisted for one month or longer. There were no exclusion criteria. All patients previously consulted an otorhinolaryngologist and all patients who suffered from unilateral tinnitus had anatomical pathology ruled out by MRI. The work-up of a patient with tinnitus consisted of standardized clinical history, a bilateral audiogram and a cervical spine radiograph.

Data assessment

A retrospective patient chart review was conducted. Data recorded from these patients were patient characteristics (age, sex), tinnitus characteristics (left side and/or right side, traumatic, duration of complaints, and age of onset), and comorbidity (self-reported hearing loss, the presence of disbalance, dizziness, and cervicalgia). The standardized bilateral clinical audiogram assessed pure tone thresholds at 125, 250, 500, 1000, 2000, 4000, and 8000 Hz. The results of the audiogram were obtained for the ear in which the tinnitus predominated. If the tinnitus was perceived as equal between both sides the average of the results of the audiogram of both sides were computed and used. The lateral cervical spine radiographs were assessed for:

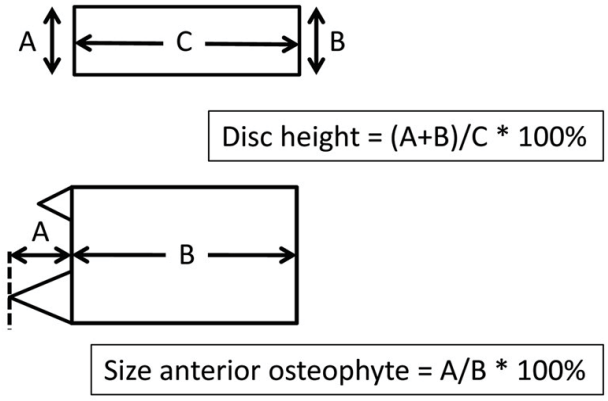

Figure 1. Procedures of measurements of disc height and of the size of anterior osteophyte.

- The angle between the posterior borders of consecutive cervical vertebrae.
- The intervertebral disc space height of the five cervical levels, as assessed by the Farfan's Measurement (FM): (anterior disc height+posterior disc height)/disc diameter×100 percent[8] (Figure 1).
- The size of the anterior osteophyte relative to the size of the cervical vertebrae, as calculated by dividing the distance of the anterior border of the largest anterior osteophyte to the anterior border of the cervical vertebrae by the width of the cervical vertebrae at the middle×100 percent (Figure 1).

Statistical methods

Statistical analysis was performed, using Minitab 16 (Minitab Inc., State College, PA, USA). A Chi-square test was used for dichotomous variables and Student's t-test was used for continuous variables. Discriminant analysis for the division in two groups was used to evaluate the correlation between hearing loss at 250 Hz (dB) and with the prevalence of unilateral and bilateral tinnitus. A value of $P<0.05$ was considered statistically significant.

RESULTS

The characteristics of the patients who came to the clinic for consultations regarding their tinnitus are shown in Table 1. Tinnitus was associated with moderate hearing in the lower frequency (125 Hz to 2 KHz), greater hearing loss in the higher frequency (4 KHz to 8 KHz), diminished cervical lordosis, diminished disc height at C5-C6 and C6-C7, and anterior osteophytes especially at the fifth and sixth cervical vertebrae.

Patients with unilateral tinnitus were compared to patients with bilateral tinnitus in Table 2. Unilateral tinnitus was associated with more self-perceived hearing loss and

Table 1. Characteristics of all patients with tinnitus (n=95).

	Prev.	Mean	SEM	Q1	Q3
Gender (M)	57%				
Age at onset tinnitus (yrs)		46.1	1.20	40.0	55.0
Unilateral	30%				
Balance disorder	40%				
Vertigo	40%				
Self-perceived hearing loss	60%				
Cervical pain	68%				
Hearing loss (dB) at:					
- 125 Hz		23.2	3.75	10.0	32.5
- 250 Hz		20.6	2.26	10.0	25.0
- 500 Hz		20.4	2.18	5.0	25.0
- 1 KHz		21.5	2.26	10.0	29.0
- 2 KHz		23.8	2.23	10.0	35.0
- 4 KHz		38.6	2.62	20.0	52.5
- 6 KHz		50.5	3.48	28.5	73.8
- 8 KHz		47.1	2.84	25.0	65.0
Angle between vertebrae (degrees):					
- C2-C7		10.7	1.35	3.0	19.5
Farfan's measurement of disc space height (%):					
- C2-C3		40.0	0.77	35.0	45.0
- C3-C4		36.7	0.99	31.0	44.0
- C4-C5		35.8	0.94	31.0	42.0
- C5-C6		28.3	0.98	20.0	36.0
- C6-C7		26.9	1.10	19.3	33.8
Size of anterior osteophyte (%) at:					
- C3		5.2	0.63	0.0	9.0
- C4		9.2	0.75	5.0	13.0
- C5		15.6	0.77	10.0	21.0
- C6		12.3	0.83	7.0	16.0

less cervical pain compared to bilateral tinnitus, but the difference was not statistically significant. In patients with unilateral tinnitus was a statistically significant lesser hearing from 250 Hz to 1 KHz compared to bilateral tinnitus. There were no statistically significant differences in radiographic measurements between groups. Multivariate analysis indicated that hearing loss at 250 Hz was the strongest variable associated with the presence of uni and bilateral tinnitus. A hearing loss of more than 23 dB was associated with a higher prevalence of unilateral tinnitus and a lower prevalence of bilateral tinnitus.

In Table 3, patients with a hearing loss of more than 23 decibels at 250 Hz in the audiogram were compared to the other patients. Patients with a hearing loss of more than 23 decibels at 250 Hz were characterized by a high prevalence of self-perceived hearing loss (92% of the patients), balance disorders (75% of the patients), vertigo (63% of the patients), and unilateral tinnitus (54% of the patients). The audiogram results showed a mean hearing loss of more than 40 decibels at all frequencies. Patients with a hearing loss at 250 Hz of 23 decibels or less have a

Table 2. Patients with unilateral tinnitus compared to patients with bilateral tinnitus [Prev.: prevalence, M: male, yrs: years, dB: decibel, Hz: Hertz, KHz: Kilohertz, SEM: Standard error of the mean. Sign: Statistical significant at $p<0.05$].

Variables	Unilateral			Bilateral			P-value
	Prev.	Mean	SEM	Prev.	Mean	SEM	
Gender (M)	68%			53%			0.184
Age at onset tinnitus (yrs)		44.9	2.5		46.6	1.4	0.540
Balance disorder	50%			36%			0.218
Vertigo	46%			38%			0.440
Self-perceived hearing loss	71%			55%			0.127
Cervical pain	54%			74%			0.055
Hearing loss (dB) at:							
125 Hz		28.3	6.8		19.6	4.2	0.291
250 Hz		29.8	4.8		16.5	2.3	0.017 sign.
500 Hz		28.5	4.4		16.8	2.4	0.023 sign.
1 KHz		29.6	4.9		18.0	2.3	0.038 sign.
2 KHz		28.7	4.6		21.6	2.5	0.182
4 KHz		46.1	5.3		35.3	2.9	0.082
6 KHz		56.6	7.0		47.8	3.9	0.285
8 KHz		53.3	5.2		44.5	3.4	0.162
Angle between vertebrae (degrees):							
C2-C7		13.9	2.4		9.2	1.6	0.115
Farfan's measurement of disc space height (%):							
C2-C3		39.7	1.5		40.1	0.9	0.805
C3-C4		35.4	2.0		37.1	1.1	0.457
C4-C5		35.2	1.7		35.9	1.1	0.724
C5-C6		28.4	1.9		28.2	1.2	0.902
C6-C7		26.5	2.1		27.4	1.3	0.720
Size of anterior osteophyte (%) at:							
C3		5.5	1.1		5.1	0.8	0.765
C4		9.6	1.2		9.0	1.0	0.729
C5		15.8	1.3		15.6	1.0	0.879
C6		11.9	1.5		12.2	1.0	0.836

high prevalence of bilateral tinnitus and a low prevalence of balance disorders and vertigo. The audiogram results showed statistically significant more hearing loss at all frequencies for the patients with a hearing loss of more than 23 decibels. There were no statistically significant differences in the radiographic measurement of the cervical spine in both groups.

DISCUSSION

This study showed that unilateral tinnitus is associated with more hearing loss than bilateral tinnitus. There were no significant radiographic differences found in the cervical spine. These results agree with a study that found moderate to severe hearing loss at the low-frequencies in patients with unilateral tinnitus[9]. However, in another study no significant audiologic differences were found between uni and bilateral tinnitus[7].

In our study, statistical analysis indicated two subgroups of tinnitus which can be differentiated by a hearing loss at 250 Hz of 23 decibels or more. Patients with a hearing loss at 250 Hz of 23 decibels or less were characterized by a high prevalence of bilateral tinnitus. The other subgroup was characterized by a high prevalence of self-

Table 3. Patients with a hearing loss at 250 Hz of more than 23 decibels compared to patients with a hearing loss at 250 Hz of 23 decibels or less [Prev.: prevalence, M: male, yrs: years, dB: decibel, Hz: Hertz, KHz: Kilohertz, SEM: Standard error of the mean. Sign.: Statistical significant at $p<0.05$].

Variables	Hearing loss at 250 Hz of more than 23 decibels			Hearing loss at 250 Hz of 23 decibels or less			P-value	
	Prev.	Mean	SEM	Prev.	Mean	SEM		
Prevalence	29%			71%				
Gender (M)	58%			63%			0.670	
Age at onset tinnitus (yrs)		43.3	2.8		47.5	1.3	0.186	
Unilateral	54%			22%			0.004	Sign.
Balance disorder	75%			27%			0.000	Sign.
Vertigo	63%			30%			0.006	Sign.
Self-perceived hearing loss	92%			53%			0.001	Sign.
Cervical pain	65%			65%			0.985	
Hearing loss (dB) at:								
125 Hz		51.3	5.5		12.6	1.6	0.000	Sign.
250 Hz		46.8	4.5		10.2	0.7	0.000	Sign.
500 Hz		45.5	4.3		9.9	0.8	0.000	Sign.
1 KHz		45.2	5.3		12.1	1.1	0.000	Sign.
2 KHz		42.2	5.2		16.3	1.7	0.000	Sign.
4 KHz		54.9	6.0		32.8	2.5	0.002	Sign.
6 KHz		71.4	9.1		44.9	3.2	0.018	Sign.
8 KHz		60.9	6.0		41.6	3.0	0.007	Sign.
Angle between vertebrae (degrees):								
C2-C7		13.7	2.8		9.1	1.7	0.173	
Farfan's measurement of disc space height (%):								
C2-C3		39.2	1.8		40.6	0.9	0.475	
C3-C4		36.6	1.8		36.8	1.3	0.937	
C4-C5		35.6	1.8		35.1	1.2	0.802	
C5-C6		28.9	2.0		27.2	1.2	0.477	
C6-C7		24.6	1.9		28.0	1.3	0.15	
Size of anterior osteophyte (%) at:								
C3		6.8	1.5		4.6	0.8	0.191	
C4		9.5	1.2		9.6	1.1	0.951	
C5		17.0	1.6		14.9	1.0	0.242	
C6		12.1	1.5		12.1	1.1	0.986	

perceived hearing loss (92% of the patients), balance disorders (75% of the patients), vertigo (63% of the patients), and unilateral tinnitus (54% of the patients). These characteristics resembling the clinical features of otogenic tinnitus. Hence, hearing loss at 250 Hz of more than 23 decibels could differentiate between the otogenic tinnitus and other forms of tinnitus, such as somatosensory tinnitus. Radiologic abnormalities of the cervical spine are expected in somatosensory tinnitus, because head and neck adjustments are the second most frequent tinnitus modulator region[10]. However, we found no radiologic differences of the cervical spine between patients with unilateral tinnitus and patients with bilateral tinnitus.

In practice, imaging is advocated for patients with unilateral tinnitus and asymmetric hearing loss to exclude pathology at the cerebellopontine angle[11]. All MRIs performed for the unilateral tinnitus patients were normal. If cerebral pathology is not present, reduced blood circulation to the inner ear should be considered as a cause of the otogenic subtype of tinnitus with hearing impairment[12]. Sympathetic fibres innervating the cochlea play a role in the control of cochlear blood flow with direct sympathetic-induced vasoconstriction. Blockade of the sympathetic fibers to the cochlea can lead to increased cochlear blood flow. Tinnitus patients with a hearing loss greater than 22 dB at 250 Hz were found to be good candidates for a sympathetic blockade to reduce tinnitus[13].

A limitation of the study is that the patients we examined may not be representative of all tinnitus sufferers, because of the severity of the tinnitus in our patients. Patients who are referred to our clinic are patients with tinnitus that are not responding to conventional treatment or patients in which the severity of the complaints was a serious issue. Another limitation of our study is the lack of a control group containing participants without tinnitus. Comparing the radiographic measurements of the cervical spine and the audiological results of the control group to those of patients with unilateral and bilateral tinnitus could give more information about the pathogenesis of tinnitus.

CONCLUSION

To conclude, our study supports the findings that there are two subgroups of patients with tinnitus with two different pathogenetic mechanisms. Hearing loss at 250Hz of more than 23 decibels could differentiate between otogenic and non-otogenic tinnitus. This cut-off value can be decisive for additional research or treatment.

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