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Original Article

Somatic Modulation in Tinnitus: Clinical Characteristics and Treatment Outcomes

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OBJECTIVES: We aimed to evaluate the clinical significance of the somatic modulation test in patients with tinnitus and analyze the treatment outcomes.

MATERIALS AND METHODS: Medical records of patients who visited the tinnitus clinic at a local university hospital between October 2018 and April 2019 were retrospectively reviewed.

RESULTS: The data of 81 patients were analyzed for this study, of which 61.7% (n=51) showed tinnitus modulation after one or more neck or jaw maneuvers. Patients with narrow-band noise tinnitus tended to show maneuver-induced modulation more frequently than those with pure-tone tinnitus (85.7% vs. 53.3%, p=0.010). Neck maneuvers reduced tinnitus loudness in 29.6% of the patients, while 27.2% of patients (n=22) reported worsening of tinnitus loudness, and 23.5% of patients (n=19) reported tinnitus suppression after jaw maneuvers. None of the patients with noise exposure history reported tinnitus modulation. Backward regression analysis revealed that age was an independent risk factor for improvement (Exp [B]=0.703, p=0.034, 95% CI=0.508-0.974). However, somatic modulation or medical treatments targeting somatic modulation were not related to improvement.

CONCLUSION: Patients showing modulation after neck or jaw maneuvers have specific clinical characteristics. However, somatic modulation itself does not affect the final treatment outcome.

KEYWORDS: Tinnitus, somatic modulation, prognosis

INTRODUCTION

Tinnitus is a condition characterized by the perception of sound in the ear or head in the absence of an external source. In general, auditory deprivation as a result of aging or noise exposure leads to neural plasticity in the central auditory pathway as well as the non-auditory areas.[1,2] In sudden deafness, which is the most representative disease showing an acute-onset hearing loss, the better contralateral hearing increases the incidence rate of tinnitus because it can maximize the impact of acute hearing loss.[3] However, the pathophysiology of tinnitus has a complex nature. Among tinnitus sufferers with normal hearing, the mechanism might differ between patients with bilateral tinnitus and unilateral tinnitus on the basis of their audiometric profiles.[1] In addition, tinnitus has been reported even in the better-hearing side in approximately 8% of tinnitus patients.[4] Thus, auditory deprivation is not the sole factor for predicting tinnitus.

On another note, some researchers have emphasized that the auditory system is linked to the somatosensory system.[5] The somatic influence on auditory perception may be one of the basic characteristics of the auditory system, irrespective of the accompanying tinnitus.[6] For tinnitus, the following findings indicate the presence of somatosensory influence: (1) neck or jaw pain that simultaneously appears with tinnitus, (2) neck/jaw symptoms that are simultaneously aggravated with tinnitus, (3) head or neck trauma preceding tinnitus, (4) varying pitch, loudness, and/or location, and (5) discrepancies in audiogram and unilateral tinnitus.[7] Interestingly, patients showing these findings have a higher chance of modulating their tinnitus with somatic manipulation, including (1) voluntary movement of the head, neck, jaw, or eyes, (2) somatic maneuvers, and (3) by applying pressure on myofascial

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trigger points.[7,8] Theoretically, all these findings can be used as clues for both diagnosis and further treatment of somatosensory tinnitus.[8,9] Targeting the treatment of somatic disorders underlying tinnitus, such as temporomandibular joint (TMJ) disorder or craniocervical disorders, is important for the correct management of somatosensory tinnitus.[10] These treatments include applying pressure on myofascial trigger points; electrical stimulation of the median nerve, scalp, or auricle; transcutaneous electrical nerve stimulation or transcranial direct current stimulation; and acupuncture.[9,10] In this study, we aimed to compare the characteristics of tinnitus patients and their somatic modulation test results and analyze their treatment outcomes according to the results of the somatic modulation test.

MATERIALS AND METHODS

Patients

Patients who visited the tinnitus clinic at a local university hospital between October 2018 and April 2019 complaining of tinnitus were screened. The exclusion criteria, similar to those of our previous study, were as follows[11]: (1) Patients whose tinnitus handicap inventory (THI), Beck depression inventory (BDI), and visual analog scale (VAS, from 0 to 10, 0: no symptoms, 10: maximal symptom) scores for tinnitus loudness, awareness, annoyance, and effect on life were not obtained at the initial evaluation and (2) patients who visited the clinic only once.

A total of 119 patients were initially screened in this study. After applying the patient exclusion criteria, individual data of 81 patients were analyzed (Table 1). This patient population consisted of 56 men and 25 women with a mean age of 52±11.7 years (range: 25–80 years). Forty-nine patients had bilateral tinnitus, and 32 patients had unilateral tinnitus. The mean interval from onset to visit was 30.1±47.4 months (range: 1–240 months). In the assessments of accompanying diseases, 25.9% of the patients (n=21)had hypertension, and 3.7% of patients (n=3) had diabetes. In assessments of trauma history or noise exposure history associated with tinnitus, 9.9% of patients (n=8) reported a history of trauma occurring just before tinnitus, and 4.9% of patients(n=4) reported noise exposure history during recreation or occupation.

Documented Variables

Information regarding age; sex; duration of tinnitus; THI, BDI, and VAS scores; accompanying diseases, such as diabetes mellitus (DM) and hypertension (HTN); previous history of noise exposure and/or tinnitus-related trauma; use of medical treatment, including baclofen, clonazepam, and escitalopram; use of hearing aids; and zinc levels in the blood were collected.

Table 1. Patient characteristics

Variables		Results
Number		81
Age (years)		52.2±11.7
Sex	Male n (%)	59 (72.8)
	Female n (%)	22 (27.2)
Duration of tinnitus (Range) (months)		30.1±47.4 (1-240)
Laterality of tinnitus	Unilateral n (%)	32 (39.5)
	Bilateral n (%)	49 (60.5)
Accompanying diseases	DM n (%)	3 (3.7)
	HTN n (%)	21 (25.9)
Previous history	Trauma history n (%)	8 (9.9)
	Noise exposure n (%)	4 (4.9)
Questionnaires at initial evaluation	THI	45.2±22.7
	BDI	11.7±8.1
	VAS for loudness	3.9±2.1
	VAS for awareness	9.5±1.8
	VAS for annoyance	4.1±2.5
	VAS for effect on life	4.1±2.6
Questionnaires assessed 3 months later	(n=39)	
	THI	28.8±22.3
	BDI	8.4±7.0
Used treatment regimens	(n=39)	
	Counseling based on tinnitus retraining therapy	81 (100%)
	Environment sounds	81 (100%)
	Baclofen	6 (15.8)
	Clonazepam	20 (24.7)
	Escitalopram	8 (21.1)
	Sound generators/ Hearing aids	4 (10.9)
Hearing threshold	PTA on the right side	19.9±13.9 dB
	PTA on the left side	22.3 ± 17.8 dB
	SRT (SDS%) on the right side	9.3±11.4 (94.4±14.4%)
	SRT (SDS%) on the left side	13.7±21.3 (92.3±19.0%)

DM: diabetes mellitus; BDI: Beck depression inventory; HTN: hypertension; PTA: pure-tone average; SDS: speech discrimination score; SRT: speech reception threshold; THI: tinnitus handicap inventory; VAS: visual analog scale.
Data are presented as mean±standard deviation for numerical variables and number (%) for nominal variables.

MAIN POINTS

- Tinnitus was modulated in 61.7% of patients after one or more neck or jaw maneuvers.
- Somatic modulation did not occur in patients after previous noise exposure.
- Patients with narrow band noise tinnitus tended to show maneuver-induced modulation more frequently than those with pure-tone tinnitus.
- A younger age was an independent, favorable prognostic factor for improvement, but somatic modulation itself did not affect final treatment outcomes significantly.

Table 2. Applied somatic modulation test

Site	No	Maximal pressure is applied to the following sites without causing distress or discomfort to the patient	Results	Increase	Decrease	No change
Neck maneuvers	Maneuver 1	Forehead				
	Maneuver 2	Occiput				
	Maneuver 3	Left temple				
	Maneuver 4	Right temple				
	Maneuver 5	Left mastoid attachment of the sternocleidomastoid				
	Maneuver 6	Right mastoid attachment of the sternocleidomastoid				
	Maneuver 7	With the head turned to the left, resist the torsional force on the left zygoma				
	Maneuver 8	With the head turned to the left, resist the torsional force on the right zygoma				
	Maneuver 9	With the head turned to the right and tilted to the left, resist the force applied to the left temple				
	Maneuver 10	With the head turned to the left and tilted to the right, resist the force applied to the right temple				
	Maneuver 11	Clenching the teeth				
	Maneuver 12	Opening of the mouth				
	Maneuver 13	Opening of the mouth with restorative pressure				
	Maneuver 14	Protrusion of the jaw				
	Maneuver 15	Protrusion of the jaw with restorative pressure				
	Maneuver 16	Sliding of the jaw to the left				
	Maneuver 17	Sliding of the jaw to the left with restorative pressure				
	Maneuver 18	Sliding of the jaw to the right				
	Maneuver 19	Sliding of the jaw to the right with restorative pressure				

Pure-tone audiometry, speech audiometry, tinnitogram analysis, otoacoustic emission assessment, and auditory brainstem response assessment were performed. The tinnitus pitch at a single frequency of unilateral or bilateral tinnitus was documented. However, cases showing discrepancies in the tinnitus pitch between both ears and/or complex tinnitus sounds of more than two types were not included. For characteristics, tinnitus was basically classified as pure-tone or narrow-band noise (NBN). If the patients' tinnitus did not match one of these two categories, these data were not documented.

For the somatic modulation test, we adopted maneuvers described in the study by Won et al. [9] (Table 2). If tinnitus was modulated by at least one of the neck or jaw maneuvers, these patients were classified as showing somatic modulation.

Treatment Regimen

After the initial assessment, all patients underwent one or two counseling sessions for understanding the pathophysiology of their tinnitus and habituation. Patients with mild tinnitus distress alone received education on the use of environmental sounds. For patients with severe tinnitus distress without hearing loss, a sound generator was recommended. Patients presenting with both tinnitus distress and hearing loss were recommended hearing aids. Baclofen was prescribed for patients who showed somatic modulation and wanted some medication. For patients who had high BDI scores (more than 12) and reported their anxiety/depression and/or sleep disturbance, clonazepam was additionally prescribed after obtaining their permission.

Response to Treatment

Patients with a final improvement of ≥20 in the THI score were defined as showing improvement. In patients whose initial THI was within 20, an increase of more than 4 points was also regarded as improvement.

Statistical Analysis

Statistical analysis was similar to that performed in our previous study. [11] The χ^2 and Fisher's exact tests were used to compare the data between groups and to analyze trends. The nominal data are presented as mean, standard deviation, and range unless otherwise stated. The paired *t*-test was used to compare the pre-treatment and post-treatment (at 3 months) THI and BDI scores. Backward conditional logistic regression analysis was performed with the following variables: THI score, pure-tone or NBN type, age, results of somatic modulation test, initial tinnitus loudness expressed as dBHL, and use of baclofen for treatment. All statistical analyses were performed using the Statistical Packages for the Social Sciences (SPSS) version 26.0 software (IBM Corp., Armonk, NY, USA). A $p<0.05$ was considered statistically significant.

RESULTS

Psychoacoustics of tinnitus

Forty-five patients (68.2%) reported that their tinnitus was similar to pure-tone, and 21 patients (31.8%) reported their tinnitus as NBN. The other 15 patients described their tinnitus as not classifiable into either of the two categories. Sixty patients reported their tin-

nitus pitch as 4.97±3.19 kHz (range: 0.125–14 kHz) and loudness as 42.50±23.90 dBHL (range: 5–105 dBHL). In the questionnaire assessments, the THI and BDI scores at the initial evaluation were 45.2±22.7 and 11.7±8.1, respectively. The VAS score for loudness was 3.9±2.1, as described in Table 1.

Characteristics of somatic modulation

Age, sex, and accompanying diseases showed no association with somatic modulation (p>0.05). None of the patients who had any previous noise exposure history reported tinnitus modulation by neck or jaw maneuvers. In contrast, tinnitus was modulated in 66.2% of patients (n = 51) without a noise exposure history (p=0.016, Fisher's exact test).

Of the total patient population, 61.7% of patients (n = 51) showed tinnitus modulation after one or more neck or jaw maneuvers. While 85.7% of patients (n = 18) with NBN-like tinnitus reported that their tinnitus was modulated by maneuvers, somatic modulation was noted in only 53.3% of patients (n = 24) with pure-tone tinnitus (p=0.011; χ^2 analysis).

Tinnitus loudness decreased in 29.6% of patients (n = 24), and 8.6% of patients (n = 7) reported an increase in tinnitus loudness directly after the neck maneuvers (Figure 1a). In contrast, 23.5% of the patients (n = 19) reported a transient decrease in loudness and 27.2% of patients (n = 22) reported a transient aggravation of tinnitus loudness (Figure 1b). However, the most common outcome of both manipulations was that there was no change in tinnitus loudness.

Relationship between treatment outcomes and somatic modulation

A total of 39 patients visited the hospital after 3 months for follow-up, and the treatment regimens used for these patients are described in Table 1. Among these, 61.5% of patients (n = 24) showed tinnitus improvement based on an increase of 20 points or more on the THI scale. THI improvement did not differ according to somatic modulation; the history of noise exposure or tinnitus-related trauma; accompanying DM and HTN; treatment with drugs, including baclofen, clonazepam, and escitalopram; use of hearing aids; sex; laterality; zinc levels, and pure-tone audiometry results (p>0.05). Backward logistic regression analysis revealed that younger age was an independent, favorable prognostic factor for improvement (Table 3). Although a low THI score and the absence of somatic modulation were included as variables for regression, these were statistically insignificant (p>0.05).

DISCUSSION

The key findings of our study are as follows: (1) Tinnitus was modulated in 61.7% of patients after one or more neck or jaw maneuvers; (2) somatic modulation did not occur in patients after previous noise exposure; and (3) a younger age was an independent, favorable prognostic factor for improvement, but somatic modulation itself did not affect final treatment outcomes significantly.

With regard to the prevalence of somatic modulation, our findings are consistent with those of previous studies. A previous study that used the same maneuvers reported that tinnitus was modulated in 57.1% of patients tested.[9] Similarly, 57.9% to 63.2% of patients experienced tinnitus modulation by at least one of the nine muscle contraction maneuvers, with no significant test–retest differences.[12] Levine et al. reported that while somatic modulation could have occurred in 80% of patients with ongoing tinnitus and patients with symmetric hearing, asymmetrically modulated tinnitus may have benefited from various treatment modalities.[13]

We also found that none of the patients with a previous noise exposure history showed any somatic modulation. As noise exposure can induce hearing loss at some frequencies and may also trigger the generation of tinnitus, the tinnitus in these cases may have been

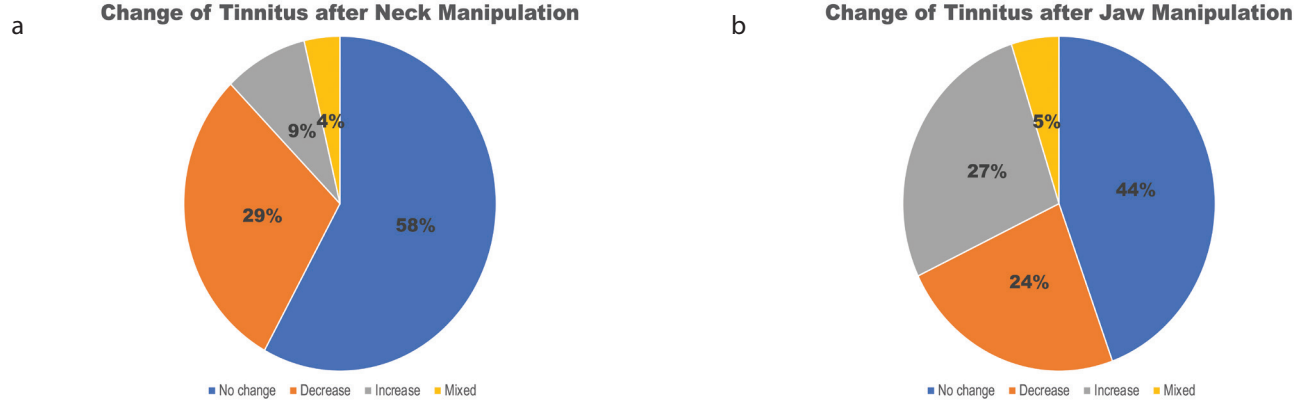

Figure 1. a, b. Changes in tinnitus after somatic manipulation. (a) Changes after neck maneuvers. (b) Changes after jaw maneuvers.

Table 3. Results of backward logistic regression analysis for final improvement

Variables	B	SE	Sig.	EXP(B)	95% CI
Initial THI	–0.75	0.045	0.092	0.927	0.850-1.012
Age	–0.352	0.166	0.034	0.703	0.508-0.974
Somatic modulation	3.814	2.468	0.122	45.349	0.359-5721.586

CI: confidence interval; SE: standard error; Sig.: significance; THI: tinnitus handicap inventory

caused mainly by changes in the auditory pathway, not by the auditory–somatic alterations that occur as a result of cross-modal synaptic activity within the dorsal cochlear nucleus or are associated with activation of the somatosensory, somatomotor, and visual–motor systems.[14] In short, we assume that tinnitus after noise exposure referred to auditory origin tinnitus, which could be a clue for distinguishing actual tinnitus from malingering after noise exposure. In addition, for somatosensory tinnitus, a self-reported history of somatic dysfunction and modulation of tinnitus are frequently observed, especially in patients with TMJ disorders.[15,16] These findings highlight the importance of precise history-taking as well as physical examination.

We also found that somatic modulation did not differ with age, which was consistent with the findings of a previous study.[15] However, age was an independent risk factor for improvement in this study. We assume that this might be because we treated all patients in the same manner; after initial evaluation, all patients underwent counseling sessions based on the tinnitus retraining therapy. Thus, older patients might not understand the pathophysiology of their own tinnitus well. In addition, the education level might differ according to age.

This study had several limitations. First, if more detailed history-taking for factors such as TMJ dysfunction or other craniocervical dysfunction and noise exposure or tinnitus-related trauma history had been performed, a more precise analysis would have been possible. However, the scope of the analyses was restricted by the retrospective medical chart review. Second, we did not analyze whether the hearing thresholds were symmetrical because this judgment might be too subjective in most cases. Traditionally, the diagnosis of somatic tinnitus may require symmetric hearing loss or normal hearing level.[13] However, we did not use these criteria due to their relative ambiguity. Third, the range of duration of tinnitus was too wide (from 1 to 240 months). Categorizing the cases into acute or chronic tinnitus might have yielded clearer outcomes. Thus, further studies should focus on acute or chronic tinnitus. Fourth, all patients with tinnitus and 25 dB of hearing loss or more were recommended the use of hearing aids. However, only 4 patients chose it. This relatively low compliance might have also affected the final results.

CONCLUSION

Patients whose tinnitus is modulated by neck or jaw maneuvers have their own clinical characteristics. Tinnitus was modulated in 61.7% of patients after one or more neck or jaw maneuvers. Patients with NBN tinnitus and those without noise exposure history tended to have somatosensory tinnitus modulated by a series of maneuvers. However, somatic modulation itself did not affect the final treatment outcome.

Ethics Committee Approval: This study was approved by the Institutional Review Board (IRB) of Eulji University (EMC IRB 2019-08-003).

Informed Consent: N/A.

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Conflict of Interest: The authors have no conflict of interest to declare.

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