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Missed Hearing Loss Affects the Outcome of Compound Sound Therapy Upon Tinnitus

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Abstract

Objective: We wished to investigate the effect and importance of precision testing of tinnitus on tinnitus treatment using compound acoustic therapy.

Methods: Forty-six patients with a normal hearing threshold were recruited. Clinical data (tinnitus frequency, tinnitus loudness, minimum masking level, Residual Inhibition (RI)) were documented and Feldman masking curves drawn. A hearing test was undertaken using steps of 1/24 octaves and 2 dB. Each test required determination of the Tinnitus Handicap Index (THI) and patients using a Visual Analog Scale (VAS) for tinnitus according to their own experience. Then, patients underwent acoustic therapy.

Results: Thirty-two cases were RI-positive and 14 cases were RI-negative. Thirty-four patients had hearing loss according to PTA using the 1/24-octave hearing test. All of them shown Notched curve in audiogram. Differences in the mean scores for THI and VAS between patients with hearing loss before and after treatment were significant ($p<0.01$), whereas differences between the 12 patients with normal hearing before and after treatment were not.

Conclusion: "Notched Hearing Loss" (NHL) affected the outcome of compound acoustic therapy for tinnitus patients. The effect of acoustic therapy for patients with NHL was better than that for patients with normal hearing. Therefore, conducting a detailed hearing test for tinnitus patients is important.

Keywords: Tinnitus; Hearing loss; Acoustic therapy

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Introduction

"Subjective tinnitus" is the perception of a sound in the absence of a corresponding external sound source and is, therefore, considered to be an "auditory phantom perception" [1]. It is a common problem for millions of individuals and can have serious negative effects on quality of life. Approximately 10% of adults in the USA suffer from tinnitus [2]. It has been hypothesized that: (i) Tinnitus is associated with hearing loss [3,4] but many tinnitus patients have a normal audiogram (i.e., no direct sign of hearing impairment); (ii) there might be different tinnitus-generating mechanisms between hearing loss and normal hearing [5]. The relationship between hearing loss and tinnitus has been researched extensively [6], and several different treatment methods have been developed.

"Residual Inhibition" (RI) is an important indicator for predicting the effect of acoustic therapy. It is broadly accepted that RI-positive tinnitus patients can benefit from acoustic therapy, whereas RI-negative patients cannot [7]. However, previously we showed that acoustic therapy could also lead to symptom relief in RI-negative tinnitus patients with a normal hearing threshold. That result suggested that other factors may affect the efficacy of complex acoustic therapy in patients with normal hearing.

Xiong et al. suggested that the precision hearing (non-octave) test may detect occult hearing loss among tinnitus patients with normal hearing [8]. We wished to ascertain if occult hearing loss was one of the factors affecting the therapeutic outcome of acoustic therapy.

Patients and Methods

Ethics approval was obtained by the Ethics Committee of the first affiliated hospital of Sun Yat-

Sen University. All patients signed an informed consent after reading a detailed information leaflet.

Study cohort

A total of 168 tinnitus patients visited the outpatient clinic of the First Affiliated Hospital of Sun Yat-Sen University (Guangzhou, China) from September 2014 to December 2015. Forty-six patients with a normal hearing threshold were recruited in our study, among whom 26 were male (mean age, 35.73 ± 11.15 years) and 20 were female (28.95 ± 13.38 years). Forty patients had unilateral tinnitus (20 had tinnitus in the right ear and 20 had tinnitus in the left ear) and the other six patients had bilateral tinnitus. All recruited patients could communicate and cooperate appropriately, and declared no history of trauma or ear surgery, diseases of the central nervous system, or cardiovascular/cerebrovascular diseases (e.g., hypertension). Patients with objective (e.g., vasogenic) tinnitus and those with conductive hearing loss were excluded. All patients underwent routine otologic examination of the external auditory canal and confirmed that the tympanic membrane was intact.

Pure-tone audiometry (PTA)

The hearing test was undertaken in a soundproof room in the Hearing Center of the First Affiliated Hospital within Sun Yat-Sen University. The background noise was <30 dB. Binaural air conduction and the bone conduction threshold were tested at 0.25, 0.5, 1, 2, 4, and 8 kHz, respectively, using a two-channel clinical audiometer (Conera™; Madsen, Copenhagen, Denmark). According to results, patients were divided into groups based on decibel hearing level (dB HL) according to PTA: "normal hearing" (≤ 25 dB HL); "mild hearing loss" (26 to 40); "moderate hearing loss" (41 to 55); moderate-to-severe hearing loss (56 to 70); severe hearing loss (71 to 90); "very severe hearing loss" (>90).

Tinnitus matching

Clinical data (tinnitus frequency, tinnitus loudness, minimum masking level, RI) were documented and Feldman masking curves drawn using a TTS-1000 system (WeiDi, Beijing, China) with TinniFit™ software (Bozzy, Beijing, China). On the basis of conventional PTA and tinnitus matching, we took the tinnitus pitch as the central frequency and the width of the 500-Hz frequency range. Then, the hearing test was undertaken using steps of 1/24 octaves and 2 dB.

Tinnitus questionnaire

Each test required determination of the Tinnitus Handicap Index (THI) and patients using a Visual Analog Scale (VAS) for tinnitus according to their own experience (Table 1). The THI is calculated by answering 25 questions and is divided into three sub-modules: Functional, Emotional, and Severity. Each request can be answered by "yes", "sometimes" or "none". If one selects "yes", it is recorded as 4 points, "sometimes" as 2 points, "none" as 0 points, with the maximum score being 100 points in total. The THI is divided into four levels: the first level (0 to 16 points) denotes "no handicap"; second level (18 to 36 points) denotes "mild handicap"; third level (38 to 56 points) denotes "moderate handicap"; fourth level (58 to 100 points) denotes "severe handicap".

Acoustic therapy

TinniFit provided sound files (rain, birdsong, snoring). All of these natural sounds had been processed and could be divided into frequencies (low, medium, high) and multi-band sounds to cover the patient's tinnitus pitch (which was acquired during tinnitus matching). Patients could choose different sound files according to their educational background, living habits, or personal preferences. Indeed, patients could provide their preferred music so that technicians could undertake frequency analyses and select three clips that covered the tinnitus pitch. Each clip of music lasted about 20 min to 30 min. When the music clip was on, the chosen natural sounds faded in and out intermittently in the first 10 min, not exceeding 1 min each time. Synthetic music files were measured using Audition™ CS6 (Adobe, San Jose, CA, USA) to unify the sound pressure. Music loudness were adjusted to 10 dB to 15 dB above the ringing-loudness threshold to mask tinnitus without causing discomfort.

Short-term outcome

Participants were asked to wear a headset and listen to individual music clips. Three music clips were used as a cycle, with ≥ 3 cycles a day and this process lasted 3 months. Data on tinnitus frequency, tinnitus loudness, RI, mean THI score and mean VAS score were collected before and after acoustic therapy. The difference in efficacy between the two groups was compared.

Statistical analyses

Data were analyzed using SPSS v18.0 (IBM, Armonk, NY, USA). The Student's t-test, logistic regression, and linear regression were undertaken for parameter and non-parametric analyses, respectively. $P<0.05$ was considered significant.

Results

Basic data

Among 46 tinnitus patients with normal PTA, 32 were RI-positive and 14 were RI-negative (Table 1). Thirty-four patients had hearing loss according to PTA using the 1/24-octave hearing test, and their mean hearing threshold was 25.8 ± 7.2 dB HL, mean tinnitus frequency was 5940 ± 1078 Hz, mean tinnitus threshold was 32.6 ± 4.7 dB HL, and mean tinnitus loudness was 2.8 ± 0.2 dB Sensation Level (SL). For the other 12 participants, the mean hearing threshold was 10.7 ± 5.1 dB HL, mean tinnitus frequency was 6583 ± 1083 Hz, mean tinnitus threshold was 21.3 ± 5.7 dB HL, and mean tinnitus loudness was 3.3 ± 1.5 dB SL (Figure 1).

Acoustic therapy

Sound therapy alleviated symptoms in RI-positive and RI-negative patients. Forty-six patients were followed up after 2 months of sound therapy. The 32 RI-positive patients had a mean THI score of 21.75 ± 11.67 and mean VAS score of 2.97 ± 1.06. The 14 RI-negative patients showed a mean THI score of 21.75 ± 11.67 points and mean VAS score of 2.97 ± 1.06. Comparison of the two groups before and after treatment is shown as Figure 2.

Table 1: The score of THI and VAS patients before sound therapy.

RI	THI	THI sub-items			VAS
		E	F	C	
RI positive n=32	33.38 ± 16.23	15.63 ± 8.78	11.88 ± 6.85	5.88 ± 3.13	4.38 ± 1.62
RI negative n=14	29.86 ± 20.15	12.29 ± 8.03	10.86 ± 7.09	6.43 ± 5.50	3.93 ± 1.69

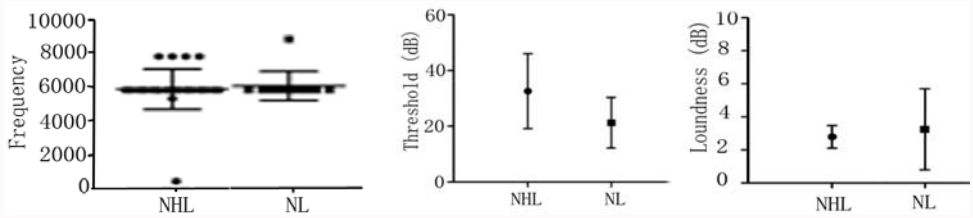

Figure 1: The character of the difference group tinnitus patients.
The tinnitus patients were subdivided into two groups, one group has hearing loss with precision hearing test (NHL: Notched-like Hearing Loss), the other group has not (NL: Normal Hearing). The two groups have the similar character of tinnitus frequency and loudness.

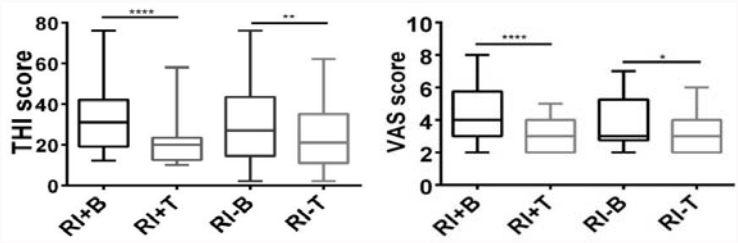

Figure 2: Both Residual inhibition positive and negative patients shown elevate by sound therapy.
RI+B refers to RI positive patients before sound therapy; RI+T refers to RI positive patients after sound therapy; RI-B refers to RI negative patients before sound therapy; RI-T refers to RI negative patients after sound therapy.

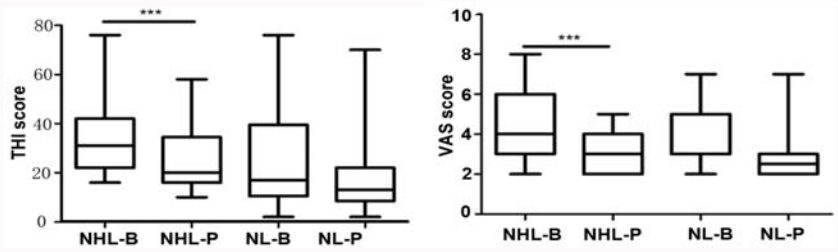

Figure 3: The patients having hearing loss acquired better sound therapy effect.
NHL-B: Precision pure threshold audiometric detected hearing loss patients before sound therapy; NHL-P: Precision pure threshold audiometric detected hearing loss patients after sound therapy; NL-B: Fine pure threshold audiometric still shown normal hearing patients before sound therapy; NL-P: Fine pure threshold audiometric still shown normal hearing patients after sound therapy.

Efficacy of acoustic therapy

We compared the therapeutic efficacy between patients with hearing loss and those with normal hearing. We found that 34 of 46 patients with normal PTA had Notched Hearing Loss (NHL) according to the 1/24-octave hearing test. This NHL was located mostly at 6000 Hz, the maximum threshold was 58 dB, the minimum threshold was 26 dB, and the mean threshold was 35 dB. The mean THI score before treatment was 34.41 ± 15.27, and the mean VAS score was 4.41 ± 1.64. The mean THI score after treatment was 24.59 ± 12.07, and the mean VAS score was 3.21 ± 1.09.

The other 12 patients were found to have normal hearing using the 1/24-octave hearing test. The mean THI score before treatment was 26.33 ± 21.92, and the mean VAS score was 3.75 ± 1.60. After treatment, the mean THI score was 20.33 ± 19.99, and the mean VAS score was 3.08 ± 1.68.

There was a significant difference in the mean THI score and mean VAS score between patients with hearing loss before and after treatment ($p<0.01$). However, there was no significant difference in the mean THI score ($t=1.91$, $df=11$, $p=0.081$) and mean VAS score ($t=2$, $df=11$, $p=0.071$) between the 12 patients with normal hearing (Figure 3). It is suggested that the occult hearing loss patients more sensitivity to the composite acoustic therapy.

Discussion

Tinnitus is common, but few treatments have been shown to be efficacious [9-12]. Acoustic therapy for tinnitus is recommended by the American Academy of Otolaryngology Head and Neck Surgery. Acoustic therapy is based on application of exogenous sounds to alter the perception of, or reaction to, tinnitus [13]. Acoustic therapy works primarily through masking, diverting attention, retraining, and neuromodulation. Since the discovery of tinnitus masking, various sound-based treatments have been studied and used widely. In general, it is believed that RI is the main indicator for predicting the clinical outcome of acoustic therapy [14]. However, we found that for patients with normal hearing in the normal pure-tone threshold test, occult hearing loss also affected the outcome of complex acoustic therapy. Hence, occult hearing loss was one of the indicators for judging the effect of acoustic therapy. The mechanism of RI is still not completely uncovered [5]; sound-evoked suppression of spontaneous firing has frequently been thought play the key role in the psychoacoustic phenomenon [15]. The magnitude of tinnitus reduction and duration of RI, largely depend on the intensity, duration, and spectrum of the sound used to induce RI, the depth and duration of RI increased with the center frequency of the band-passed noise stimuli. We almost unknown about the RI effects in normal

PTA tinnitus.

We evaluated 46 tinnitus patients with normal hearing. In the precision hearing test, 34 patients had different degrees of NHL. This type of hearing loss mostly fell between frequencies we usually tested and, therefore, might be missed in conventional PTA. Patients with NHL had better outcomes after acoustic therapy, and the mean THI score and mean VAS score improved significantly, suggesting that composite acoustic therapy is closely related to the overall state of the patient's auditory pathway. Patients with NHL maybe have different spontaneous firing pattern compared with normal hearing tinnitus patients. The NHL-type audiograms suggested that a small portion of an abnormality of the auditory conduction pathway required a more detailed test to detect it.

Various types of acoustic therapy are available for tinnitus: white noise, CR neuromodulation® [16] and Neuromonics® [17]. Due to patient and ethical issues, we used only one type of composite sound in acoustic therapy. Our further studies will try more different sound on NHL and focus on the efficacy of the acoustic therapy and find out whether have similar results.

Conclusion

Occult hearing loss has an effect on the complex acoustic therapy of patients with tinnitus. When using acoustic therapy, patients with occult hearing loss have better outcomes than patients with significant hearing loss, thereby making a precision hearing test are needed to carry out on tinnitus patients with normal hearing when use conventional PTA methods.

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