The Association Between Cochlear and Retrocochlear Disorder with Tinnitus with Normal Hearing Thresholds

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ORIGINAL ARTICLE

The Association Between Cochlear and Retrocochlear Disorders with Tinnitus with Normal Hearing Thresholds

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Abstract Tinnitus is the perception of hearing the sound without any sound stimulus. It is a symptom of abnormality in a form of conductive disorder when it comes from the outer ear canal and middle ear. A tinnitus complaint has a normal hearing threshold but it has been not fully recognized its causes. Thus, an objective evaluation is needed to locate the abnormality by using OAE and BERA test. To analyze the association of TEOAE, DPOAE, and BERA to locate cochlear and retrocochlear disorders in tinnitus patients with normal hearing threshold. The study was conducted from August to November 2010 until the number of samples was fulfilled in Outpatient Clinic and Audiology Unit in Department of Otolaryngology-Head and Neck Surgery, Dr. Soetomo General Hospital Surabaya. The inclusion criteria in this study included: patients aged 20–50 years old, hearing threshold of ≤ 25 dB, type A tympanogram. The comparison and the association test of TEOAE, DPOAE and BERA in tinnitus group were: TEOAE–BERA analysis result using Mc Nemar obtained $p = 0.006$, Kappa $p = 0.047$, likelihood ratio $p = 0.066$, and the result of DPOAE–BERA analysis using Mc Nemar obtained $p = 0.008$, Kappa $p = 0.439$, likelihood ratio $p = 0.336$. There was a difference in the results of DPOAE examination between tinnitus patients with normal hearing threshold and the control group. There was no difference in TEOAE and BERA test results between tinnitus patients with normal hearing threshold and the control group. This indicates an abnormality in the cochlear.

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Background

Tinnitus is the perception of hearing the sound without any sound stimulus [1, 2]. In daily life, tinnitus causes hearing loss which can degrade the quality of life. This is what causes the patient to visit a specialist doctor of Otolaryngology, to evaluate the auditory function with audiometry. It is revealed that there are conductive hearing loss, sensorineural hearing loss and mixed hearing loss. However, in 30% of patients with tinnitus, there is a normal threshold (audiogram within normal limits), providing an impression that there is no hearing loss problem in tinnitus and is often overlooked [3].

The complaint of tinnitus with normal hearing threshold with normal limit audiogram results requires further evaluation as the cause of tinnitus is not known clearly. Tinnitus itself is presummed to have abnormalities in the peripheral hearing pathways, cochlea, retrocochlea to the central, and the possibility of lesions in more than one place. The evaluation on the basis of audiogram alone was not enough to describe the abnormality/location of the cause of tinnitus. The association between the presence or absence of cochlear and retrocochlear abnormalities with normal hearing threshold is still not widely known [1, 4].

A study in tinnitus patients with normal hearing threshold using TEOAE test obtained the pass results of 64%, while the DPOAE obtained the pass result of 90% [5]. The same study conducted by Ami et al. in 2007 using DPOAE test obtained that the amplitude values of tinnitus patients with normal hearing threshold decreased about

93%, and tinnitus with hearing loss decreased to 96% [6]. In 2008, there was an abnormal picture on 47% of BERA results of tinnitus patients who had a normal audiogram. Reported in other literatures, there were 31–40% had abnormal BERA description. Although 53% of tinnitus patients had a normal BERA picture, there was a significant elongation in wave I, III, and V compared with the control group that had normal audiogram without tinnitus, and the widening of interpeak III–V and increasing ratio of amplitude V/I [7]. Tinnitus is not a disease but is a symptom of abnormality. It can be a conductive disorder if it comes from the outer ear canal and middle ear. It can be in a form of sensorineural disturbance caused by the irritative or degenerative process of the auditory tract from the cochlear hair cells, the retrocochlea to the hearing center [8, 9]. The occurence of external hair cell damage affects the changes in the resistance of the cochlear system which is considered responsible for persistent waves in the inner ear to induce the emulsion of spontaneous otoacoustic and tinnitus [10, 11]. In the retrocochlear system, there is a spontaneous activity in auditoric nerve fibers caused by metabolic disorders that can cause tinnitus [2, 12].

A tinnitus complaint has a normal hearing threshold but it has been not fully recognized its causes. Thus, the objective of the study is to analyze the association of TEOAE, DPOAE, and BERA to locate cochlear and retrocochlear disorders in tinnitus patients with normal hearing threshold.

Methods

This study was an analytic observational research with cross sectional design. The study was conducted from August to November 2010 until the number of samples was fulfilled in Outpatient Unit and Audiology Unit in Department of Otolaryngology-Head and Neck Surgery, Dr. Soetomo General Hospital Surabaya. The samples of the study were tinnitus patients with normal hearing threshold and patients without tinnitus as the comparison group.

The inclusion criteria in this study included: patients aged 20–50 years old, hearing threshold of $\leq$ 25 dB, tympanogram type A. The exclusion criteria in this study included as follows; had experienced head injuries, had external and middle ear infections, such as otitis externa and otitis media, have undergone external and middle ear surgery, such as mastoidectomy, exposure to explosion and tinnitus duration of each recurrence was less than 5 min. The data was collected by using consecutive sampling technique.

This research used several research tools such as data collection sheet, ENT-HNS examination tools: head lamp, grooved hook, sharp hook, round hook, ear speculum, nasal speculum, tongue spatula, otoscope, pure tone audiometry type AD 229E, Inter acoustic timpanometer type AT 35, TEOAE and DPOAE Cochlea Scan type RS 232 Biologic System Corp, BERA type EPA 25. The data analysis began with the examination of ENT-HN by the doctor in charge and the researchers, then a consultation in Audiology Unit to conduct hearing examination with pure tone audiometry. The subjects were asked to sit quietly, listened to the headphones and asked to respond the sound. Afterwards, it was conducted the frequency examination of 250, 500, 1000, 2000, 4000 and 8000 Hz in both ears in the impermeable room. The examination of tympanometry was conducted to ensure the condition of middle ear. If the type A was included and the type B and C were excluded in the study, TEOAE and DPOAE tests were performed in the impermeable room by the researchers. The subjects can sit or lie down and were inserted in the corresponding probe in the outer ear tube consisting of transducers and microphones. During the examination the subjects were not allowed to speak or swallow. The TEOAE and DPOAE tests were performed by the researchers and specialists of ENT-HN in the Neurotology Division. BERA test was performed in a low-noise room, and the subjects were mounted electrodes and insertphone. It was conducted a record of electrical potential in the brain as a result of sound stimulation by trained personnel.

The collected data was arranged in data collection sheets in the form of tables and statistically processed by using Fischer exact test, Mann–Whitney test, independent *t* test, Mc Nemar test and Kappa association test and Likelihood Ratio test. The data was analyzed using SPSS software (SPSS. Inc. Chicago IL).

Results

Basic Data

The basic data of the study in this study included age, gender, occupation, education level, tinnitus location, duration of complaint and time of tinnitus. In this study, the most tinnitus group was between the ages of 20–35 years old of 6 subjects (42.86%), while the control group was also between the ages of 20–35 years old as many as 9 subjects (81.81%). Based on the Independent *t* test, 2 tailed obtained $p = 0.10$. There was no significant difference between the age of tinnitus and control group ($p > 0.05$). The age of the tinnitus group had the mean age of 39.07 (SD = 11.042), and the control group of 32.18 (SD = 8.438) (Table 1).

Based on the gender distribution in tinnitus and control group, there were more female patients than male patients.

Table 1 Age distribution

Age (years)	Tinnitus group	Control group
20–35	6 (42.86%)	9 (81.81%)
36–45	4 (28.57%)	1 (9.09%)
46–55	4 (28.57%)	1 (9.09%)
Total	14	11

Table 2 Gender distribution

Gender	Tinnitus group	Control group	Total
Female	10 (71.43%)	8 (72.72%)	18
Male	4 (28.57%)	3 (27.27%)	7
Total	14 (100%)	11 (100%)	25

Based on the Fisher's Exact test, the gender distribution in both groups obtained $p = 1.000$. There was no significant difference in gender distribution in tinnitus and control group ($p > 0.05$) (Table 2).

Based on the occupation distribution in tinnitus and control group, the most occupation in tinnitus group was housewife as many as 5 subjects (35.71%), while there were 9 subjects (81.81%) in the control group who worked as doctor/paramedic (Table 3). Based on the distribution of educational level in tinnitus group, there were 5 subjects (35.71%) that had attained their undergraduate degree, whereas there were 8 subjects (72.73%) educated undergraduate in the control group. Based on the Mann–Whitney test, the education level of both groups obtained $p = 0.120$. There was no significant difference in the distribution of education level between the two groups ($p > 0.05$) (Table 4). The frequency of the location of tinnitus in the right ear was 5 (35.71%), the left ear was 3 (21.43%), and the left and right ear was 6 (42.86%) (Table 5). In the tinnitus group, the complaint can appear on one side or both sides at the same time (bilateral).

Table 5 The ear location frequency of tinnitus complaints

Ear	Quantity	%
Right	5	35.71
Left	3	21.43
Right and left	6	42.86
Total	14	100

Table 6 The recurrence time in tinnitus complaints

Recurrence time	Quantity	%
Noon	2	14.28
Night	6	42.86
Throughout the day	6	42.86
Total	14	100

The recurrence time of tinnitus complaints were divided into three: during the day, night and throughout the day. The results of recurrence time during the day were 2 subjects (14.28%), 6 subjects at night (42.86%) and 6 subjects all day (42.86%) (Table 6). Based on the period of tinnitus complaint, the fastest patient who came for examination in 2 months was 1 subject (7.14%), the longest 1 subject in

Table 3 Occupation distribution

Occupation	Tinnitus group	Control group	Total
Housewives	5 (35.71%)	0 (0%)	5 (20%)
Machine operator	2 (14.29%)	0 (0%)	2 (8%)
Civil servant	3 (21.43%)	2 (18.18%)	5 (20%)
Doctor/paramedic	1 (7.14%)	9 (81.81%)	10 (40%)
Entreupreneur	1 (7.14%)	0 (0%)	1 (4%)
Baby sitter	2 (14.29%)	0 (0%)	2 (8%)
Total	14 (100%)	11 (100%)	25 (100%)

Table 4 Education level distribution

Group	Uneducated	ES	SHS	Diploma	Undergraduate	Total
Tinnitus	1 (7.14%)	2 (14.29%)	3 (21.43%)	3 (21.43%)	5 (35.71%)	14 (100%)
Control	0 (0%)	0 (0%)	3 (27.27%)	0 (0%)	8 (72.73%)	11 (100%)
Total	1 (4%)	2 (8%)	6 (24%)	3 (12%)	13 (52%)	25 (100%)

Table 7 The period of tinnitus complaints

Period of complaint (month)	Quantity	%
2	1	7.14
3	1	7.14
6	3	21.42
12	4	28.57
24	2	14.29
36	1	7.14
Total	14	100

Table 8 The TEOAE test results in tinnitus and control groups

TEOAE	Pass	Refer	Total
Tinnitus group	11 (78.57%)	3 (21.43%)	14 (100%)
Control group	11 (100%)	0 (0%)	11 (100%)
Total	22 (88%)	3 (12%)	25 (100%)

36 months or 3 years (7.14%) and the mean was 16.64 months (SD = 18.579) (Table 7).

The Evaluation Results of Otoacoustic Emission

The Results of Transient Evoked Otoacoustic Emission

The results of TEOAE test in Pass tinnitus group were 11 (78.57%) and Refer was 3 (21.43%) while in Pass control group was 11 (100%) and there was no Refer control group (Table 8). The comparison test results between the two groups using Fischer exact test obtained $p = 0.230$. There was no significant difference in TEOAE results of tinnitus and control group ($p > 0.05$).

The Evaluation Results of Distortion Product Otoacoustic Emission

Based on the results of DPOAE test in tinnitus and control group, Pass was 9 (64.29%) and Refer was 5 (35.71%), while the control group of Pass was 11 (100%) and Refer was absent (Table 9). Fisher's exact test results obtained $p = 0.046$. There was a significant difference in DPOAE examination results in the tinnitus and control group

Table 9 The DPOAE test results in tinnitus and control groups

DPOAE	Tinnitus group	Control group
Pass	9 (64.29%)	11 (100%)
Refer	5 915.71%)	0 (0%)
Total	14	11

($p < 0.05$). The result Fisher's exact test at frequency 1 kHz obtained $p = 0.003$, frequency 4 kHz obtained $p = 0.020$ and frequency 6 kHz obtained $p = 0.008$. There was a significant difference in DPOAE test results at the frequency of 1, 4 and 6 kHz between the tinnitus and control group ($p < 0.05$). However, there was no significant difference at the frequency of 2 and 3 kHz ($p > 0.05$) (Table 10).

The results of DPOAE examination by using the correlation test between tinnitus and control group with contingency coefficient obtained $p = 0.027$. There was a significant correlation in the DPOAE results between the tinnitus and control group ($p < 0.05$). The correlation test was conducted at each frequency with the results: frequency 1 kHz obtained $p = 0.002$, frequency 4 kHz obtained $p = 0.013$, and frequency 6 kHz obtained $p = 0.006$. There was a significant correlation in the results of DPOAE between the tinnitus and control groups at the three frequencies ($p < 0.05$). However, there was no significant correlation at frequencies 2 and 3 kHz ($p > 0.05$) (Table 11).

The Evaluation Results of Brainstem Evoked Response Auditory

The Independent t test obtained $p = 0.088$. There was no significant difference in BERA results of tinnitus and control group ($p > 0.05$). The results of evaluation of each wave with Independent t test obtained $p = 0.044$. There was a significant difference only at the wave latency I of BERA test between tinnitus and control group ($p < 0.05$). On the other hand, there was no significant difference in the other wave latency ($p > 0.05$). The correlation test of latency wave I examination by using BERA in tinnitus and control group with contingency coefficient obtained $p = 0.144$. There was no significant correlation at the latency of wave I between tinnitus and control group ($p > 0.05$) (Table 12).

The Comparison of TEOAE, DPOAE and BERA Tests

The test results are statistically stated to be the same if it fulfilled the following requirements: Mc Nemar's comparative test result is not significant ($p > 0.05$), Kappa association test is significant ($p < 0.05$) or Likelihood Ratio is significant ($p < 0.05$). The comparison and the association test of TEOAE, DPOAE and BERA in tinnitus group were: TEOAE–DPOAE analysis result using Mc Nemar obtained $p = 0.688$, Kappa $p = 0.538$, likelihood ratio $p = 0.560$, TEOAE–BERA analysis result using Mc Nemar obtained $p = 0.006$, Kappa $p = 0.047$, likelihood ratio $p = 0.066$, and the result of DPOAE–BERA analysis

Table 10 The DPOAE test results of each frequency in tinnitus and control groups

DPOAOE frequency (kHz)	Tinnitus		Control		*p*
	Pass	Refer	Pass	Refer	
1	6 (42.85%)	8 (57.14%)	11 (100%)	0 (0%)	0.003*
2	10 (71.42%)	4 (28.57%)	11 (100%)	0 (0%)	0.105
3	10 (71.42%)	4 (28.57%)	11 (100%)	0 (0%)	0.105
4	8 (57.14%)	6 (42.85%)	11 (100%)	0 (0%)	0.020*
6	7 (50%)	7 (50%)	11 (100%)	0 (0%)	0.008*

* indicates significant correlation ($p < 0.05$)

Table 11 The correlation of DPOAE results of each frequency in tinnitus and control groups

DPOAOE frequency (kHz)	Tinnitus		Control		*p*
	Pass	Refer	Pass	Refer	
1	6 (42.85%)	8 (57.14%)	11 (100%)	0 (0%)	0.002*
2	10 (71.42%)	4 (28.57%)	11 (100%)	0 (0%)	0.053
3	10 (71.42%)	4 (28.57%)	11 (100%)	0 (0%)	0.053
4	8 (57.14%)	6 (42.85%)	11 (100%)	0 (0%)	0.013
6	7 (50%)	7 (50%)	11 (100%)	0 (0%)	0.006

* indicates significant correlation ($p < 0.05$)

Table 12 The results of BERA test in tinnitus and control group

BERA wave	Tinnitus		Control		*p*
	Mean (ms)	SD	Mean (ms)	SD	
I	1.43	0.13	1.35	0.04	0.044*
III	3.62	0.34	3.42	0.17	0.088
V	5.53	0.33	5.36	0.17	0.119
I–III	2.19	0.33	2.09	0.16	0.332
III–V	1.90	0.13	1.91	0.16	0.819
1–V	4.09	0.31	3.85	0.66	0.219

* indicates significant correlation ($p < 0.05$)

using Mc Nemar obtained $p = 0.008$, Kappa $p = 0.439$, likelihood ratio $p = 0.336$ (Table 13).

Discussion

There was no correlation between TEOAE, DPOAE and BERA to locate the abnormality in tinnitus patients with normal hearing threshold. TEOAE, DPOAE and BERA tests can not replace each other.

In this study, the tinnitus group obtained ear frequency that had tinnitus complaint in right ear of 5 subjects, 3 subjects in left ear and 6 subjects in bilateral ears. This is in contrast to a research in Canada that the location of the left ear is 1.5 times more frequent than the right [13].

Table 13 The comparison test between TEOAE, DPOAE and BERA results in the tinnitus group

Tests	Statistical test	*p*
TEOAE–DPOAE	Mc Nemar	0.688
	Kappa	0.538
	Likelihood Ratio	0.560
TEOAE–BERA	Mc Nemar	0.006
	Kappa	0.047
	Likelihood Ratio	0.066
DPOAE–BERA	Mc Nemar	0.008
	Kappa	0.439
	Likelihood Ratio	0.336

Presumably, the location of the ear is also related to the habit of using hand to work [2, 14]. It seems that tinnitus complaints occured more common in the night and throughout the day. This is in accordance with the previous research if tinnitus more clearly is heard at night or in a quiet conditions, the patient will more clearly hear the sound of tinnitus while going to rest causing the disruption in everyday life [9, 14]. The fastest period of tinnitus complaints that came to the test was 12 months. It shows that during 72 months of tinnitus complaints, decreased hearing threshold has not started to appear.

It is in accordance with previous studies on tinnitus patients with normal hearing threshold using TEOAE test obtained pass result [5]. In contrast, the previous study obtained refer result by using TEOAE test than patients without tinnitus [15].

The prior research states that if the pure tone audiometry examination results are routinely performed on the frequency of 250–8000 Hz tinnitus patients with normal hearing threshold, the evaluation by using a higher frequency (above 8000 Hz) obtained hearing loss in the form of sensorineural hearing loss [16]. In the control group, 100% pass was obtained. A previous study mentioned that TEOAE waves will appear/pass in 90% of ear that has a normal hearing threshold [15, 17].

The results of the tinnitus group evaluation of this study were consistent with the results of previous studies that there were significant differences between the tinnitus group and the control group. The difference in intensity used in this study with previous studies seems to have an effect; thus, if the intensity used is improved on the subsequent examination, it can obtain refer results [15]. In contrast to previous studies, there was a statistically significant difference in all frequencies examined [15]. The occurence of significantly different test results in the tinnitus and control group using DPOAE in this study supported the findings in various literatures that OHC dysfunction in the cochlea plays an important role as the cause of tinnitus with normal hearing threshold [2, 6, 10, 12, 15].

The results of the analysis show that tinnitus with normal hearing threshold will affect the results of DPAOE. BERA analysis obtained abnormal results. This percentage is not much different than the previous studies [7].

In contrast to previous studies that found a significant difference in wave latency III and V, the difference can be caused due to differences in the number of samples of this study. If the evaluation is conducted on a larger number of samples, there may be abnormalities in the wave latency III and V. It can also be caused by the late emergence of hearing loss in this study sample [7].

BERA examination in this study used click stimulus of 12.1, intensity of 80 dB, and frequency of 2000 Hz. This is in accordance with the previous research. Frequency of 2000 Hz is the frequency that is often conducted on BERA test, while click stimulus of 12.1 is a minimal stimulus compared to routine BERA test of 31.1. The use of minimal click aims to evaluate the changes in the wave even with small stimuli [7, 18].

Another difference in the results of this study with other literatures can be due to the difference in standard normal numbers used. In the previous study, to determine the control patients who had normal hearing thresholds, there were no abnormalities in the cochlea. In this study, the control patients were determined based on the inclusion criteria of pure tone audiometry < 25 dB and normal tympanogram [7].

There was refer in both examinations that indicates a cochlear abnormality, especially in the OHC. The TEOAE results were not significantly different between the two groups, whereas DPOAE was significantly different in both groups. It is because TEOAE was more sensitive at low frequency, ranging from 500 to 4 kHz whereas DPOAE was more sensitive at high frequency [11, 19]. The situation is in accordance with the theory stated by Jastreboff who said that most cases of tinnitus derived from abnormalities in the cochlea, especially OHC at high frequencies [15]. There were statistically significant differences in the results of DPOAE and wave I BERA and this is consistent with previous studies which have resulted in DPOAE and BERA evaluation abnormalities in wave latency I. The presence of tinnitus is likely due to changes in the efferent nervous system and OHC affecting each other [20]. DPOAE and BERA is a fairly sensitive examination tool. However, not all examination flashlights have both tools. Alternatively, SISI test can be used to detect abnormalities in cochlea and Tone Decayto detect the abnormalities in retrocochlea.

Conclusion

There was a difference in the results of DPOAE examination between tinnitus patients with normal hearing threshold and the control group. There was no difference in TEOAE and BERA examination results between the tinnitus and control group. This indicates an abnormality in the cochlea.

There was no correlation between TEOAE, DPOAE and BERA results. Furthermore, TEOAE, DPOAE and BERA tests can not replace each other. DPOAE can be considered as a test for tinnitus with normal hearing threshold.

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