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Quantitative Electroencephalography and Tinnitus: A Case Study

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Abstract: We report changes in quantitative electroencephalography activity in a male tinnitus patient when his tinnitus suddenly disappeared. Topographical illustration of the quantitative electroencephalography data showed beta foci in T_3 and C_4 with tinnitus, which resolved on spontaneous remission of the tinnitus. Comparison of the power spectra in the presence and absence of tinnitus revealed significant changes of a 16-Hz band. Also, a significant increase in alpha power was observed after remission of the tinnitus.

Key Words: average total power; beta focus; delta, theta, alpha, and beta frequency bands; quantitative EEG; tinnitus

Tinnitus is defined as a sensory disorder of auditory perception, reflecting an aberrant auditory signal produced by interference in the excitatory-inhibitory processes involved in neurotransmission [1]. Many people suffer from such phantom sounds, and recent studies indicate involvement of different brain regions in the pathogenesis of tinnitus [2–5]. Previously, Weiler et al. [3] reported significant differences in the quantitative electroencephalography (QEEG) pattern between tinnitus patients and normal control subjects. In our case study, we report acute electroencephalographic (EEG) changes observed with spontaneous remission of tinnitus.

METHODS

Patient

A 55-year-old right-handed male patient presented in our institute with the chief complaint of tinnitus, a symptom that had been present for 36 months. The tinnitus was located in both ears, with the sound level in the right ear greater than in the left ear. The sound had the quality of a hiss of constant duration. Significant history included essential hypertension. With signed informed consent, the patient was subjected to a computer-assisted EEG analysis.

Quantitative Electroencephalography

The brain waves (EEG signals) were obtained through a Neurosearch 24 instrument (Lexicor Medical Technology, Inc., Boulder, CO) by placing 19 electrodes on the scalp in a standard international (10/20) pattern. The EEG signals from each electrode were amplified independently by matched differential amplifiers with less than 2 mV peak-to-peak noise; input impedance of more than a 70-MΩ differential; common mode rejection of more than 90 dB at 60 Hz; a high-pass filter of 2 Hz; and a low-pass filter of 32 Hz. Analog to digital conversion of the signal was achieved with a 12-bit A/D converter, with the sampling interval governed by a 50-kHz crystal oscillator.

All EEG data were collected under controlled conditions with the subject reclining comfortably in an arm chair and with eyes closed in a sound-attenuated, electrically shielded room. Unless stated otherwise, data used for topographical color maps were screened manually for eye blink movements, and only eye blink–free epochs were used in the preparation of quantitative results, including spectral averages and topographical maps. Statistical calculations were performed using only artifact-screened data.

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Table 1. Comparison of Total Average Power of Frequency Bands During Periods With and Without Tinnitus

Condition	Delta (μV^2)	Theta (μV^2)	Alpha (μV^2)	Beta (μV^2)
With tinnitus	11.8 ± 0.6	8.0 ± 0.3	12.9 ± 0.9	12.7 ± 0.5
Without tinnitus	9.1 ± 0.4[a]	6.7 ± 0.3[a]	18.2 ± 1.1[b]	7.3 ± 0.2[a]

[a] $p < .001$.
[b] $p < .0002$.

RESULTS

Average Total Power

The average total power for a subject is calculated by averaging the total power from each of the 19 electrode leads. The average total power for the male tinnitus patient (23.7 ± 0.5 μV^2) was significantly lower than the average total power as compared to the period without tinnitus (31.0 ± 1.1 μV^2; $p < .0001$).

Calculation of Total Average Power for the Delta, Theta, Alpha, and Beta Frequency Bands

Average total power was calculated for the following four frequency bands: delta (2–4 Hz), theta (4–7 Hz), alpha (8–13 Hz), and beta (14–21 Hz). In the presence of tinnitus, a significant increased total average power was recorded for the delta, theta, and beta bands as compared to the tinnitus-free period. The total average power of the alpha band, however, was increased significantly after remission of the tinnitus (Table 1). Subdivision of the alpha band into $alpha_1$, $alpha_2$, and $alpha_3$ revealed a significant increase for all three alpha bands when tinnitus disappeared (Table 2). Further analysis of the spectra of the beta frequency band (14–21 Hz) showed a significant reduction in power of the 16-Hz band at the following sites: C_4, T_4, T_6, F_7, T_3, and C_3, with a highly significant change in C_4 (Table 3).

Power Spectrum

Power spectrum analysis indicated a reduced alpha peak in the presence of tinnitus (Fig. 1A) as compared to the tinnitus-free period (see Fig. 1B). In the presence of tin-

Table 2. Calculation of the Total Average Power for Three Alpha Bands in the Presence and Absence of Tinnitus

Condition	$Alpha_1$ (μV^2)	$Alpha_2$ (μV^2)	$Alpha_3$ (μV^2)
With tinnitus	2.8 ± 0.1	7.7 ± 0.8	6.5 ± 0.5
Without tinnitus	3.9 ± 0.2*	11.5 ± 0.8*	9.1 ± 0.6*

* $p < .001$.

Table 3. Calculation of the Average Power for the 16-Hz Band for Different Electrode Sites

Electrode Site	16-Hz Band With Tinnitus (μV^2)	16-Hz Without Tinnitus (μV^2)	Percentage of Change
C_4	13.7 ± 2.1	3.1 ± 0.6[a]	+442
T_6	5.5 ± 0.8	2.8 ± 0.4[b]	+196
T_4	6.8 ± 1.2	2.2 ± 0.5[b]	+309
T_3	9.8 ± 5.5	1.5 ± 0.3[b]	+653
C_3	4.6 ± 0.7	2.1 ± 0.5[b]	+219
F_7	3.4 ± 0.8	1.4 ± 0.4[b]	+243

[a] $p < .0002$.
[b] $p < .01$.

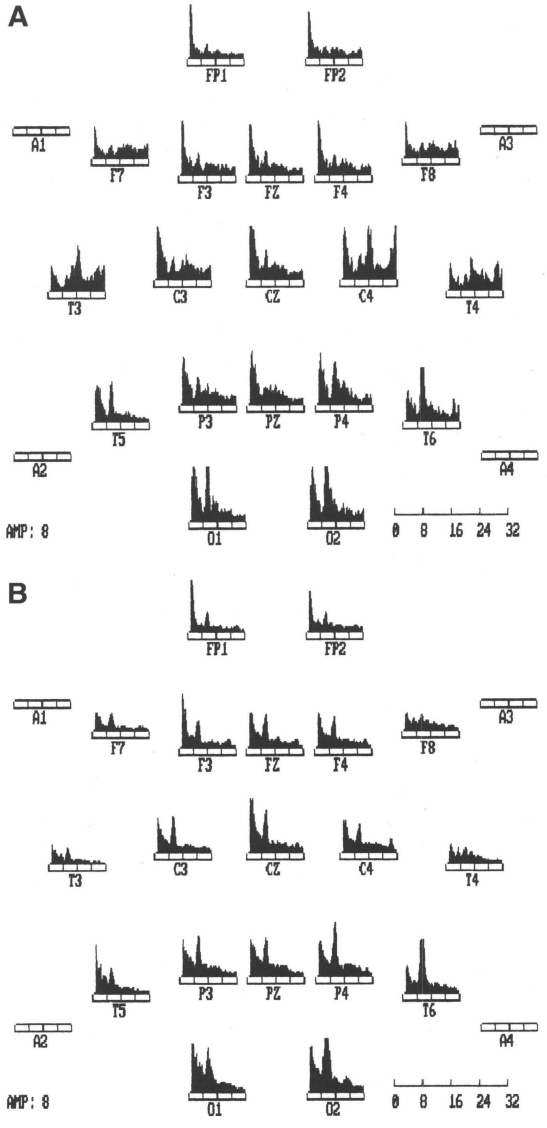

Figure 1. (A) Power spectrum during the presence of tinnitus. (B) Power spectrum after spontaneous remission of tinnitus.

nitus, a discrete beta band with a frequency of 16 Hz could be demonstrated in C_4 and T_3 (see Fig. 1A). This beta peak is reduced significantly during the tinnitus-free period (see Fig. 1B and Table 3).

Illustration of Brain Electrical Activity Mapping in the Presence and Absence of Tinnitus

The topographical data clearly indicate the presence of beta foci in C_4 and in T_3 in the presence of tinnitus. During the tinnitus-free interval, these foci no longer were present. However, the distribution pattern for the delta, theta, and alpha frequency bands remained unchanged.

DISCUSSION

We investigated the QEEG changes after an unexpected remission of tinnitus in a male individual who suffered the disorder for 3 years. In the presence of tinnitus, the total average power recorded ($23.7 \pm 0.5\ \mu V^2$) was significantly lower than the total average power recorded after remission of tinnitus ($31.1 \pm 1.1\ \mu V^2$). These values, respectively, are very close to those reported previously for male tinnitus patients and male normal control subjects [3]. Though the previously reported results were group means for male subjects with and without tinnitus, the current findings indicate that the decreased total average power observed may be associated with the presence of the tinnitus, *not* just as a consequence of a state associated with those individuals who just happen to suffer from tinnitus.

Analysis of the power in the delta, theta, and beta frequency bands revealed a significant reduction in power in each band after remission of tinnitus. Interestingly, Rozelle et al. [6] reported increased theta power in a male head-injured person suffering from tinnitus. The reduction of theta power was paralleled by an improvement of the reported tinnitus.

The power of the alpha band, however, significantly increased in the absence of tinnitus. These changes are consistent with the earlier report of Weiler et al. [3], in which the normal control group had a level of alpha power higher than that of those in the male tinnitus group. An increase of alpha power is assumed to be associated with an increased state of relaxation.

In our case study investigation, we were able to demonstrate for the first time a significant change of a single (16-Hz) beta band, mainly in C_4, T_4, T_6, F_7, C_3, and T_3. This peak was detectable only in the presence of tinnitus. Vestibular evoked potentials indicated significant abreaction of the sensomotoric strip in tinnitus patients [5]. An interesting speculation is that a neuropathy with a 16-Hz frequency of oscillation may be related to the generation of tinnitus in male patients.

In summary, our report clearly indicates an increase of alpha power and a reduction of delta, theta, and beta power with remission of tinnitus. For the first time, however, a selective change in power for a single band (16 Hz) in relation to the presence or absence of tinnitus is described. These results might offer a possible approach for treatment of tinnitus in male subjects.

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