Pulsed Magnetic-Field Therapy: A New Concept to Treat Tinnitus?

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Abstract: Both clinical and neurophysiological data suggest that chronic tinnitus is characterized by focal brain activation. In the study reported here, pulsed magnetic-field therapy induced a highly significant increase of average total power for the delta, theta, and alpha frequency bands, predominantly within the frontal regions of the brain. We conclude that pulsed magnetic-field therapy induces changes of the electroencephalography pattern that correlated with a decrease in tinnitus symptoms.

Key Words: pulsed magnetic field therapy; quantitative EEG; therapy; tinnitus

Growing evidence suggests that changes in spontaneous activity are an important neural correlate of tinnitus, an auditory disorder characterized by the perception of sound in the absence of a corresponding acoustic stimulus. Increases in spontaneous activity (hyperactivity) can occur at various levels of the auditory system [1–3].

Most recently, a report by Eichhammer et al. [4] indicated that pulsed magnetic-field therapy (PMFT) can be successfully employed in the treatment of tinnitus. Those authors observed an increased metabolic activity of the primary auditory cortex in subjects suffering from tinnitus; however, selective stimulation (1 Hz) of these cortical regions with PMFT resulted in a considerable lessening of tinnitus. A reduction of auditory hallucinations in patients with schizophrenia was noted after the application of low-frequency repetitive transcranial magnetic stimulation (rTMS) at the left temporal-parietal cortex [5–7]. After active stimulation, a remarkable effect on tinnitus sensation occurred, endured several weeks, and was paralleled by altered cortical excitability. In terms of neuronal network, epilepsies are thought to be due to an imbalance of excitation and inhibition shifted toward elevated neuronal excitability [8].

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Studies by Weiler et al. [9–11] and Shulman et al. [12] revealed significant changes of electroencephalography (EEG) patterns in patients suffering from tinnitus as compared to normal controls. Altered EEG patterns were noted for temporal and parietal regions. After EEG-guided feedback, neurofeedback, significant changes of the EEG patterns occurred, paralleling a decrease of tinnitus sensations.

The objective of our study was to determine whether lessening of tinnitus sensations after PMFT correlates with changes of EEG parameters.

METHODS

Quantitative EEG

We obtained the brain waves (EEG signals) by using a Neurosearch 24 instrument (Lexicor Medical Technology, Inc., Boulder, CO) and placing 19 electrodes on the scalp in a standard international (10/20) pattern. We performed a quantitative EEG workup using the Electrocap (Electro-cap International, Inc., Eaton, OH). Each lead was checked separately. Impedance was judged acceptable when electrode impedance registered below 5 kΩ. The EEG signals from each electrode were independently amplified by matched differential amplifiers with less than 2 μV peak-to-peak noise; by input impedance of a >70 MΩ differential; by common mode rejection of >90 dB at 60 Hz; by a high-pass filter of 2 Hz; and by a low-pass filter of 32 Hz. Analog-to-digital conversion of the signal was achieved with a 12-bit A/D converter, with sampling interval governed by a 50-kHz crystal oscillator.

We visually inspected all EEG data for artifacts due to movements and to muscular activity before the records were subjected to quantitative analysis and interpretation. Frequency analysis was performed using a fast Fourier transform. The quantitative EEG frequency bands chosen were delta (2–4 Hz), theta (4–7 Hz), alpha (8–13 Hz), and beta (14–21 Hz). Statistical calculations were performed using only artifact-screened data.

EEG data were collected from 16 patients suffering from tinnitus. The EEG signals were recorded under controlled conditions with the subject reclining comfortably in an armchair with eyes closed in a sound-attenuated, electrically shielded room. Unless stated otherwise, the data used for topographical color maps have been manually screened for eye blink movements, and only eye blink–free epochs were used in the preparation of quantitative results, including spectral averages and topographical maps.

EEG data were recorded before and after completion of PMFT. Subsequently, the EEG data were analyzed, and epochs signals distorted by artifact (eye movements, blinks, and muscle activity) were rejected. The artifact-free data were subsequently subjected to Fourier power spectral analysis. Our study included 16 tinnitus patients. The average total power for each patient was calculated by averaging the total power from each of the 19 electrode leads.

Pulsed Magnetic-Field Therapy

We performed PMFT with a system acquired from Vitrotron GmbH, Heubach, Germany. The applicator was placed on the back of each patient's head. The maximum strength of the magnetic field amounts to approximately 5 μTesla at 100% system performance. We performed PMFT with the subjects reclining comfortably in an armchair with eyes closed in a sound-attenuated, electrically shielded room.

Questionnaires

We employed several questionnaires to evaluate the efficacy of PMFT in patients suffering from tinnitus.

Symptom Checklist 90–Revised

Patients completed the Symptom Checklist 90–Revised (SCL90R), a psychometric instrument for quantifying emotional distress, on enrollment in the program and at the end of the tinnitus treatment. The SCL90R instrument is a brief, multidimensional self-report inventory designed to screen for a broad range of psychological problems and symptoms of psychopathology. The SCL90R instrument can be useful in both the initial evaluation of patients and for measuring patient progress during treatment. The SCL90R instrument is a well-researched instrument with more than 940 research studies demonstrating its reliability, validity, and utility.

Beck Depression Inventory

The Beck Depression Inventory (BDI) is a 21-item test that is presented in multiple-choice format and purports to measure presence and degree of depression in adolescents and adults. Each of the 21-items of the BDI attempts to assess a specific symptom or attitude. The BDI was designed to assess depression independent of any particular theoretical bias.

Tinnitus Questionnaire

Psychological disturbances, such as depression, anxiety, concentration difficulties, insomnia, and hearing handicaps, are common among patients with chronic tinnitus. Different attempts have been made to assess such tinnitus-related complaints. For a description in general terms, standard instruments of clinical psychology and psychiatry were insufficient. More recent work has focused on the development of specific questionnaires directly related to distress associated with chronic tinnitus [13]. The questionnaire differentiates among dimensions of emotional and cognitive distress, intrusiveness, auditory perceptual difficulties, sleep disturbances, and somatic complaints. Additionally, we employed Shulman's tinnitus questionnaire from the Martha Entenmann Institute in New York.

RESULTS

Electroencephalographic Activity: Eyes Closed

The pre-PMFT average total power (19.19 ± 0.73 μV^2) was significantly lower than the post-PMFT average total power (22.51 ± 0.95 μV^2; $p < .0001$). Average power was calculated for the following four frequency bands (Table 1): delta (2–4 Hz), theta (4–7 Hz), alpha (8–13 Hz), and beta (14–21 Hz). The pre-PMFT average total power of these frequency bands, except for the beta band, was significantly reduced as compared to post-PMFT values (see Table 1). We performed a paired *t*-test for data analysis.

Table 1. Calculation of Total Average Power for Delta, Theta, Alpha, and Beta Frequency Bands

	Delta (μV^2)	Theta (μV^2)	Alpha (μV^2)	Beta (μV^2)
Pre-PMFT	11.41 ± 0.37	13.62 ± 0.88	39.47 ± 3.0	7.81 ± 0.31
Post-PMFT	14.26 ± 0.57	16.40 ± 1.11	44.90 ± 4.0	8.22 ± 0.30
Significance	$p < .0001$	$p < .0001$	$p < .02$	p = NS

NS = not significant; PMFT = pulsed magnetic-field therapy.

Table 2. Calculation of Total Average Power for Delta, Theta, Alpha, and Beta Frequency Bands at Single Sites

Site	Delta (μV^2)	Theta (μV^2)	Alpha (μV^2)	Beta (μV^2)
FP2				
Pre-PMFT	13.20 ± 2.10	9.81 ± 1.80	16.75 ± 2.80	4.88 ± 0.40
Post-PMFT	14.0 ± 2.0	11.88 ± 2.2***	20.88 ± 5.0	5.31 ± 0.55
FP1				
Pre-PMFT	10.38 ± 1.47	9.10 ± 1.67	16.50 ± 2.68	4.50 ± 0.43
Post-PMFT	13.44 ± 1.85***	11.13 ± 1.88***	20.56 ± 4.76	5.25 ± 0.52
F8				
Pre-PMFT	7.63 ± 0.84	7.44 ± 1.50	14.20 ± 2.28	4.50 ± 0.34
Post-PMFT	10.31 ± 1.35**	10.38 ± 2.26***	17.31 ± 4.40	5.69 ± 0.85
F3				
Pre-PMFT	12.50 ± 1.27	14.63 ± 2.45	26.56 ± 4.71	6.88 ± 0.88
Post-PMFT	17.63 ± 2.25*	15.67 ± 2.56	30.75 ± 7.15	7.63 ± 0.88
FZ				
Pre-PMFT	12.31 ± 1.10	16.20 ± 2.91	29.31 ± 5.10	7.25 ± 0.87
Post-PMFT	17.20 ± 2.60**	18.44 ± 3.10	34.44 ± 8.31	7.81 ± 1.0
CZ				
Pre-PMFT	15.56 ± 1.34	19.50 ± 4.67	42.13 ± 7.43	9.5 ± 1.52
Post-PMFT	20.81 ± 3.40**	22.63 ± 4.80	48.44 ± 12.10	9.75 ± 1.43
T6				
Pre-PMFT	9.81 ± 1.61	14.50 ± 5.10	66.88 ± 23.30	7.94 ± 1.47
Post-PMFT	12.25 ± 2.24**	16.81 ± 6.82	59.5 ± 17.6	7.75 ± 1.31

Note: Only the sites with significant changes are listed.
PMFT = pulsed magnetic-field therapy.
* $p < .005$; ** $p < .05$; *** $p < .02$.

We also performed a comparison of the average power before and after PMFT for each site. In Table 2, only the sites with significant differences are listed. Additionally, we performed a paired *t*-test for data analysis.

Questionnaires

The statistical analysis of the Goebel-Hiller tinnitus questionnaire revealed significant differences after 5 and 10 days of PMFT for emotional problems, psychological problems, and the total tinnitus score (Table 3).

Statistical analysis of Shulman's tinnitus questionnaire revealed significant differences, after 5 days of PMFT, for the items communication, concentration, and loudness (Table 4). After 10 days of PMFT, a further significant improvement was noted for profession, sleep, and annoyance. A paired *t*-test was performed for data analysis.

A paired *t*-test also was performed for data analysis of the BDI questionnaire. Before PMFT, the score was 8.25 ± 1.17; after 5 days of PMFT, the score had decreased to 6.13 ± 1.37 ($p < .05$); and after 10 days of PMFT, it had been reduced to 5.88 ± 129 ($p < .05$).

Table 3. Statistical Analysis of the Goebel-Hiller Tinnitus Questionnaire

Problem	Pre-PMFT	5 Days of PMFT	10 Days of PMFT	Significance
Emotional	10.60 ± 1.26	8.00 ± 1.16**	8.07 ± 1.08**	$p < .005$
Cognitive	6.20 ± 0.74	5.53 ± 0.60	5.60 ± 0.77	NS
Psychological	16.80 ± 1.87	13.53 ± 1.67**	13.67 ± 1.77**	$p < .01$
Annoyance	11.20 ± 0.75	8.80 ± 0.92**	9.00 ± 1.07**	$p < .005$
Hearing	5.80 ± 1.01	4.73 ± 0.96	5.20 ± 0.95	NS
Sleep	3.40 ± 0.53	3.00 ± 0.54	3.20 ± 0.45	NS
Somatic	3.00 ± 0.54	2.60 ± 0.56	2.20 ± 0.57	NS
Total tinnitus score	40.20 ± 3.93	32.67 ± 3.96**	33.27 ± 3.97**	$p < .01$

** Highly significant.
NS = not significant; PMFT = pulsed magnetic-field therapy.

Table 4. Statistical Analysis of Shulman's Tinnitus Questionnaire

Problem	Pre-PMFT	5 Days of PMFT	10 Days of PMFT	Significance
Social activities	2.57 ± 0.52	1.91 ± 0.35	1.96 ± 0.34	NS
Profession	3.17 ± 0.45	2.16 ± 0.47	1.89 ± 0.34**	$p < .005$
Communication	2.21 ± 0.35	2.21 ± 0.35**	2.39 ± 0.35**	$p < .05$
Concentration	3.79 ± 0.51	2.43 ± 0.41**	2.32 ± 0.31**	$p < .005$
Loudness	4.29 ± 0.37	3.19 ± 0.48**	3.07 ± 0.42**	$p < .001$
Sleep	3.65 ± 0.4	3.02 ± 0.5	2.74 ± 0.37**	$p < .05$
Annoyance	3.57 ± 0.34	2.72 ± 0.42	2.81 ± 0.40**	$p < .05$

** Highly significant.
NS = not significant; PMFT = pulsed magnetic-field therapy.

DISCUSSION

The rTMS technique was initially developed for mapping and measuring brain functionality. It is based on the principle that a varying magnetic field will cause an electrical current within any volume through which it passes. Electromagnets with intense electrical current are pulsed on and off immediately outside the skull. When the targeted rTMS magnetic field passes through the brain, it affects cortical neurons in a particular area. Further studies demonstrated that the suppressive effects of slow rTMS are not limited to the cortex but spread out to the related subcortical structures. Data suggest that slow rTMS reduces cortical excitability, both locally and in functionally linked cortical regions. Studies of patients with focal dystonia, epileptic seizures, and auditory hallucinations indicate symptom reductions after slow rTMS [5,6,8,14–16].

Studies performed by Roland et al. [17] and Patiakina et al. [18] demonstrated beneficial effects of low-energy PMFT in patients suffering from chronic tinnitus. Most recently, Eichhammer et al. [4] employed a neuronavigated PMFT for the treatment of tinnitus patients. A decrease of tinnitus severity was noted after 5 days of PMFT; however, this approach benefited mostly patients with an elevated metabolic activity of the primary auditory cortex [4].

To our knowledge, thus far no published reports have addressed the issue of EEG changes in tinnitus patients after PMFT. In our study, lessening of the tinnitus sensations was paralleled by changes of EEG patterns, most notably involving the slow-frequency delta and theta bands. For both frequency bands, an increase of power was noted, predominantly in the frontal region of the brain. A noteworthy development in this context is that PMFT induced EEG changes, namely for the delta and alpha frequency bands, in patients suffering from headache and multiple sclerosis [19,20].

These results indicate that PMFT can successfully be employed for the treatment of patients suffering from tinnitus. Slow rTMS is a noninvasive and easily tolerated method for altering cortical physiology and thus possibly treating brain hyperexcitability syndromes. However, further research is needed to elucidate the mechanism through which tinnitus symptoms diminish.

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