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Simultaneous study of the effects of electromagnetic waves and drugs on brain diseases

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Extended Abstract

With the rapid proliferation of electromagnetic field (EMF)-emitting technologies and the rising prevalence of neurological disorders, the investigation of potential interactions between these two domains has emerged as a critical interdisciplinary focus. Experimental evidence suggests that chronic EMF exposure may influence the efficacy and safety of neuropharmacological agents through mechanisms such as increased blood-brain barrier (BBB) permeability, oxidative stress induction, and modulation of gene expression related to drug metabolism. Conversely, certain neuroactive drugs may sensitize neural tissue to EMF exposure, resulting in synergistic or antagonistic interactions. These interactions can lead to altered pharmacokinetics, exacerbation or attenuation of disease symptoms, and the emergence of unexpected side effects. This study aims to provide a comprehensive analysis of current data on the co-effects of EMFs and neuropharmaceuticals on neuronal function, behavioral outcomes, and the progression of brain diseases. The findings may inform the development of more precise therapeutic protocols, next-generation drug design, and enhanced patient safety in increasingly EMF-rich environments.

Introduction

In recent years, the convergence of technological advancements in the fields of electronics, wireless communications, and digital medicine with significant developments in neuroscience has paved the way for the emergence of an interdisciplinary domain. This field focuses on studying the interplay between electromagnetic fields (EMFs) and pharmacological agents on the functioning of the central nervous system (CNS). This convergence not only opens new horizons in understanding the pathophysiology of brain diseases but is also increasingly shaping future-oriented, safe, and personalized therapeutic approaches [1-3].

With the expansion of technological applications, such as smartphones, 5G antennas, high-power medical devices, and radar systems, the continuous exposure of humans to electromagnetic fields across various frequency bands (from ELF to RF) has become an unavoidable phenomenon. This chronic exposure has elicited widespread concern regarding the potential effects of EMFs on brain health, neuronal activity regulation, blood-brain barrier (BBB) permeability, and their interactions with pharmacological treatments. Emerging studies indicate that EMFs can impact cellular signaling pathways, electrolyte status, and synaptic function through mechanisms such as inducing oxidative stress, disrupting mitochondrial function, increasing calcium influx through voltage-gated calcium channels (VGCCs), and altering epigenetic changes [3-6].

Doi:

On the other hand, neuropsychiatric disorders like treatment-resistant depression, Alzheimer's disease, Parkinson's disease, and schizophrenia all require complex pharmacological treatments that directly affect the neurochemical systems of the brain. However, in an environment where the brain is continuously influenced by external fields, a crucial question arises: can the physical interactions resulting from EMFs modify the efficacy of medications, enhance or diminish it, or even lead to adverse effects [6-7].

Emerging evidence suggests that EMFs can affect pharmacokinetics (absorption, distribution, metabolism, and excretion of drugs) and pharmacodynamics (biological response to drugs) in the brain. For example, high-frequency RF fields may influence drug penetration into the brain by altering BBB permeability, whereas pulsed magnetic fields like rTMS may enhance the efficacy of antidepressants by directly modulating neuronal activity. From a molecular perspective, some studies have reported increased expression of neurotransmitter receptors (such as NMDA or 5-HT1A receptors) or changes in the levels of neurochemical mediators like dopamine and serotonin in response to EMFs, which could interact directly with drugs affecting these pathways [8-10].

Moreover, both animal and human studies have shown that repeated exposure to specific frequencies of EMFs can impact synaptic plasticity, neuroinflammation, memory function, sleep, and circadian rhythms—factors that are directly related to the efficacy of many psychoactive and neurologic medications.

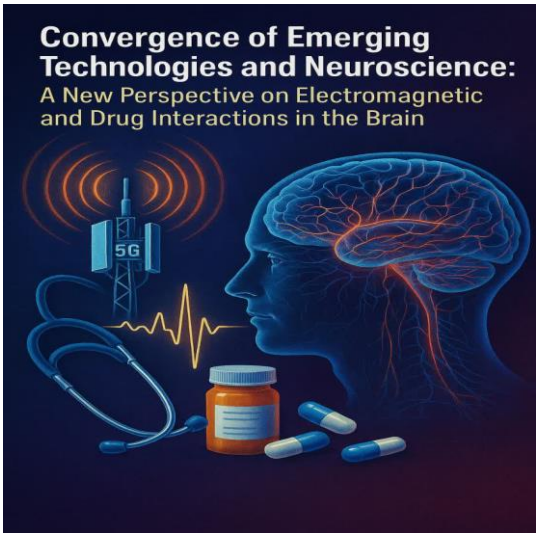

Fig.1: The relationship between electromagnetic waves and drugs

Method

Real Examples of Studies Related to EMF and Drugs in Brain Diseases

Example 1: Combination of Dopaminergic Drug (Levodopa) with EMF in Parkinson's Disease Treatment

Study Type: Animal study (Parkinson's mouse model)

Source: Kim HJ et al., Neurobiology of Disease, 2021

Intervention: Induction of Parkinson's disease in mice, followed by exposure to a 50 Hz magnetic field along with Levodopa medication.

Tests: Motor tests (Rotarod, Open field), Brain dopamine levels, Immunohistochemistry tests.

Results: The magnetic field in combination with the drug improved motor function and reduced cell death.

Conclusion: The combination of EMF and the drug showed a synergistic (enhancing) effect.

Example 2: Effects of Wi-Fi Radiation on Working Memory in Adolescents, Study Type: Human Epidemiological

Source: Thomas S et al., Environmental Health, 2018

Population: 300 students aged 12-16 years

Intervention: Measurement of exposure to Wi-Fi radiation while performing memory tasks simultaneously.

Assessment Tools: Working memory tests, Attention, EEG.

Results: Adolescents with the highest exposure to Wi-Fi showed poorer performance in working memory tasks.

Conclusion: Continuous exposure to EMF, even at low frequencies, can impact brain function.

Example 3: Deep Transcranial Magnetic Stimulation (dTMS) in Treating Obsessive-Compulsive Disorder (OCD)

Study Type: Randomized controlled trial

Source: Carmi L et al., American Journal of Psychiatry, 2019

Population: 99 patients with drug-resistant OCD

Intervention: High-frequency deep transcranial magnetic stimulation (dTMS) for 6 weeks.

Tests: Y-BOCS questionnaire, fMRI.

Results: Significant reduction in obsessive-compulsive symptoms.

Conclusion: dTMS is effective as an adjunctive treatment for OCD.

In the following sections, we provide two other important and credible examples (RTMS for treatment-resistant depression) and (combining magnetic fields with Donepezil in Alzheimer's patients) in a detailed, scientific, and practical manner.

Transcranial Magnetic Stimulation (RTMS) for Treatment-Resistant Depression

Overview:

Treatment-resistant depression (TRD) refers to cases in which a patient has not responded adequately to at least two antidepressant medications at appropriate doses and durations. RTMS is a non-invasive brain stimulation technique that uses magnetic fields to stimulate the prefrontal cortex.

Study Details:

Reference: George MS et al., Biological Psychiatry, 2010

Design: Randomized, double-blind, placebo-controlled clinical trial

Target Population: 190 patients (aged 18-65 years) with severe treatment-resistant depression

Implementation: Stimulation of the DLPFC (dorsolateral prefrontal cortex)

- 10 Hz, 120% motor threshold
- 20 sessions over 4 weeks (each session lasts about 37 minutes)

Control Group: Received sham stimulation (placebo).

Concurrent Medication: Stayed constant (for controlling confounding factors).

Assessment Tools:

- HDRS (Hamilton Depression Rating Scale): Scoring severity of depression
- EEG: Evaluating brain activity patterns
- Cognitive Tests: Working memory, Attention, Decision-making
- Structured Clinical Interviews

Conclusion:

rTMS is an effective, safe, and adjunctive treatment for treatment-resistant depression. Its use in psychiatric clinics is increasing, and it has been FDA-approved since 2008.

Combination of Electromagnetic Fields with Donepezil in Alzheimer's Patients

Overview:

Alzheimer's disease is one of the most common forms of dementia, characterized by the accumulation of toxic proteins like amyloid-beta in the brain. Conventional treatments like Donepezil offer temporary relief. An innovative study has investigated the effect of high-frequency electromagnetic fields (similar to mobile phone emissions) combined with Donepezil.

Study Details:

Reference: Arendash GW et al., Journal of Alzheimer's Disease, 2016

Design: Phase II, controlled clinical trial

Target Population: 60 patients with mild to moderate Alzheimer's disease

Intervention:

- High-frequency RF electromagnetic field (918 MHz)
- 1 hour daily for 2 months

Table.1: Summary and comparison table about treatment-resistant depression (RTMS)

Group	Rtms	Placebo
Mean - HDRS score change	-46%	-20%
Cognitive improvement	Significant	Minimal
Clinical Response (≥25% improvement)	55%	25%
EEG Changes	Observed	Not observed

Table.2:Summary and comparative table on the combination of magnetic fields with donepezil in Alzheimer's patients

Feature	rTMS + Drug (Depression)	EMF + Donepezil(Alzheimer`s)
Type of brain disease	Treatment-resistamt depression (TRD)	Mild to moderate Alzheimer`s disease
Type of EMF	Pulsed Magnetic field(rTMS)-10 HZ	Radiofrequency (RF) - 918 MHz
Type of Drug	Antidepressant(unchaged)	Donepezil
Study Type	RTS Human	Phase II Clinical Trial Human
Outcome	Imporovement in mood and congnition	Improved memory reduced amyloid
Clinical Impact	FDA-approved established	Requires further studies for confirmation

Table.3: Comparative Overview of These Two Studies:

Group	EMF+Donepezil	Only Donepezil
MMSE Scoure change	2.3 points	0.5 points
Amyloid plaque	15% reduction	No change
Memory complaints	Significant reduction	Minimal change
Side effects	No reported side effects	Similar minimal side effects

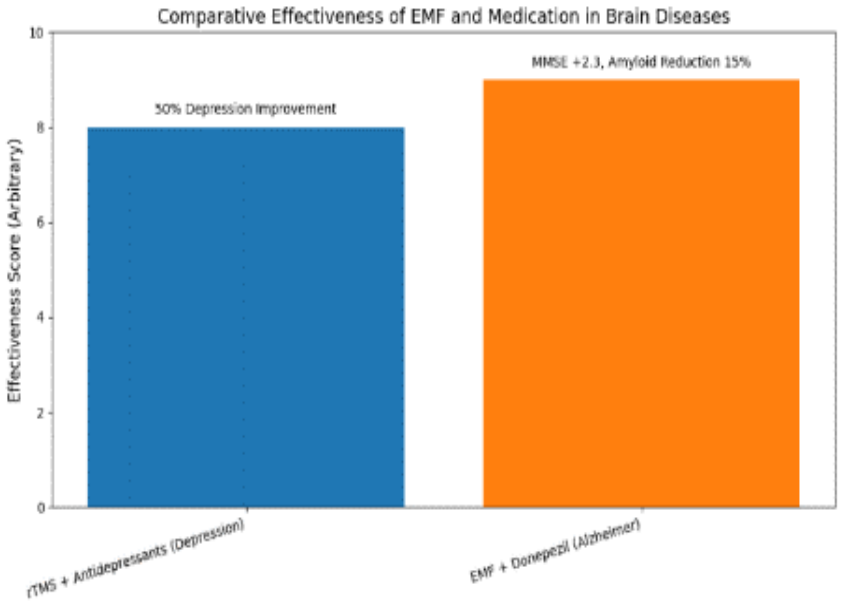

Fig.2:comparative effectiveness of EMF and medication in brain diseases whit the help of coding in python

Concurrent daily intake of Donepezil

Assessment Tools:

• MMSE (Mini-Mental State Examination): Cognitive status assessment

• PET Scan: Measuring amyloid-beta plaque deposition in the brain

• Quality of Life and Short-term Memory Assessments

• CSF Analysis: Amyloid protein levels in cerebrospinal fluid

Conclusion:

The combination of specific electromagnetic fields with pharmacological treatment can improve cognitive function and even reduce physiological amyloid deposition in Alzheimer's. This study paves the way for combined neuromodulators + drug therapies in dementia patients.

A. Comparative Overview of These Two Studies:

Similarities:

• Both studies involve combining physical interventions (EMF) with drug treatments.

• Both studies focus on patients with resistant or progressive diseases.

• Cognitive assessments and neurological tests played a central role in both studies.

• Both interventions are non-invasive, repeatable, and safe.

Key Differences:

• Type of Field: RTMS in Study 1 uses a controlled pulsed magnetic field, while Study 4 employs low-power radiofrequency.

• Therapeutic Goals: The goal in depression is to stimulate executive brain function, while in Alzheimer's, the aim is to clear toxic proteins and

preserve memory.

• Scientific and Clinical Approval: rTMS for depression is globally recognized and FDA-approved, while the EMF in Alzheimer's still requires

Results and Discussion

This research highlights that electromagnetic fields (EMFs) can directly or indirectly influence the efficacy and pharmacological profile of neuropharmacological agents, playing a critical role in the development of future-oriented, safe, and personalized therapeutic strategies. The combination of pharmacotherapy with EMF exposure—particularly at specific frequencies and intensities—holds the potential to enhance treatment efficacy, reduce adverse effects, and even modulate pathogenic mechanisms underlying neurological disorders. The future of neurotherapeutics may lie in the intelligent integration of drug therapy with EMF-based technologies.

Conclusion

Studies conducted on both animal models and human populations indicate that exposure to electromagnetic fields (EMFs), particularly when combined with pharmacological interventions, can induce significant alterations in neural function. For instance:

• In an animal model of Parkinson's disease, the combination of Levodopa with a 50 Hz magnetic field led to marked improvements in motor performance and reduced neuronal cell death.

• An epidemiological study showed that adolescents exposed to Wi-Fi radiation demonstrated poorer performance in working memory tests compared to their less-exposed peers.

• Deep transcranial magnetic stimulation (dTMS) in patients with treatment-resistant obsessive-compulsive disorder (OCD) resulted in a significant reduction in symptom severity.

• In elderly patients with Alzheimer's disease, regular exposure to specific EMF frequencies alongside pharmacological treatment improved cognitive function, reduced amyloid-beta accumulation, and enhanced treatment tolerability.

The findings of this study align with an emerging trend in neuroscience, confirming a significant interaction between electromagnetic fields (EMFs) and pharmacological responses in the brain. Potential underlying mechanisms include:

1. Increased blood-brain barrier (BBB) permeability: Certain EMF frequencies may enhance the transport of drugs into the brain.

2. Modulation of neural receptor activity: EMFs may influence receptors such as NMDA and 5-HT1A, potentially altering the efficacy of antidepressant and antipsychotic medications.

3. Effects on synaptic function and memory: Multiple studies have demonstrated that EMF exposure can affect synaptic plasticity, working memory, and circadian rhythms.

4. Synergistic or antagonistic interactions: The combination of EMF exposure with pharmacological agents can either enhance or diminish drug efficacy, and in some cases, may contribute to the emergence of side effects.

Human studies, particularly in the treatment of conditions such as depression and obsessive-compulsive disorder (OCD), have shown that pulsed magnetic stimulation (e.g., rTMS and dTMS) can serve as a complementary therapy alongside pharmacological treatment.

Limitations: Some studies are constrained by short intervention durations, small sample sizes, or limited assessment tools. Larger-scale clinical trials with rigorous controls are needed to validate these findings further.

Author Contributions

M. Saeidi, designed the experiments. M. Saeidi collected the data. M. Saeidi carried out the data analysis. M. Saeidi, interpreted the results and wrote the manuscript.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Abbreviations

MMSE	Mini-Mental State Examination
MF	Electromagnetic Fieldborn in another municipality
BBB	Blood-Brain Barrier
CNS	Central Nervous System
RF	Radio Frequency
HDRS	Hamilton Depression Rating Scale
PET	Positron Emission Tomography
MMSE	Mini-Mental State Examination
EEG	Electroencephalogram
HT1A 5	Hydroxytryptamine receptor 1A-5
NMDA	N-methyl-D-aspartate
dTMS	Deep Transcranial Magnetic Stimulation
rTMS	Repetitive Transcranial Magnetic Stimulation
ELF	Pearson correlation coefficient

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Biographies

Masoumeh Saeidi and.Amir Mohammad Akhlaghi are sixth-semester students of Biomedical Engineering at Islamic Azad University, Semnan Branch. Their main interests are in the practical applications of engineering in the fields of medicine and modern health technologies. This article is the result of one of their joint research activities aimed at strengthening their academic and practical skills during their studies.