Theoretical

A POSSIBLE PHYSICAL MECHANISM IN THE TREATMENT OF NEUROLOGIC DISORDERS WITH EXTERNALLY APPLIED PICOTESLA MAGNETIC FIELDS

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ABSTRACT

The recent clinical studies describing the treatment of some neurological disorders with an externally applied picoTesla (10^{-2} Tesla, or 10^{-8} gauss) magnetic field are considered from a physical view point. An equation relating the intrinsic (or "rest") energy of a charged particle of mass m with its energy of interaction in an externally applied magnetic field B is presented. The equation represents an initial basic physical interaction as a part of a more complex biological mechanism to explain the therapeutic effects of externally applied magnetic fields in these and other neurologic disorders.

KEYWORDS: Magnetic fields, neurologic disorders

INTRODUCTION

The existence of the brain magnetic field and the difference between the magnetic field profile of the normal brain vs the pathologic brain, has been known from the classical work of Cohen[1] and several recent works of others using the superconducting quantum interference detectors (SQUID) on patients with epilepsy and other neurologic disorders.[2-6] These investigators measured the intensity profile of the human brain magnetic field and found that it is of the order of 0.5 pT (picoTesla) or 5×10^{-9} gauss. The work of Anninos, Tsagas, and Sandyk began with the notion that an externally applied magnetic field, slightly greater than the physiologic magnetic field, but still within the range of the physiologic brain magnetic field, may "realign" the abnormal field profiles back to that associated with the normal brain.[2-4]

Equipped with a SQUID they obtained the initial magnetoencephalograph (MEG) profile, providing them with the foci, frequency, and intensity of the abnormal brain magnetic field. Subsequently, they used an array of small coils, contained in a flexible plastic patch attached to a patient's cranium, for treating several neurologic disorders, including epilepsy and multiple sclerosis. The specific focus areas, frequency, and field intensity were kept within the range of the pathologic MEG. They reported observable improvement in the post treatment MEG measurement and clinical examination of these patients. Recently Sandyk, using a similarly applied external magnetic field, confirmed their study by limiting the type of neurologic disorder to Parkinson's disease, and demonstrated with statistical significance the prolonged reduction of tremor in the hands of patients.[5]

THEORY

Several years prior to the above experimental works, Jacobson proposed an equation that the intensity B of the externally applied magnetic field can be specified for a pathologic particle (molecules, viruses, or bacteria) of mass m by Equation [1],

$$mc^2 = q_j vBl \qquad [1]$$

where c is the velocity of light in vacuum, q_j represents a unit charge *i.e.,* $q_j = 1$ coulomb, by defining electromotive force as energy per unit charge, v is the velocity of the carrier or "string" in which the particle exists, and 1 is its dimension. The "string" can be of a submicroscopic to macroscopic dimension.[7-9] The mc^2 is the intrinsic energy of the known or suspected pathogenic particle. The particle could be an abnormal portion of DNA or RNA, glycoprotein, virus, bacteria, abnormal chromosome, or portion of a chromosome. If the mass m of the particle is known, and a reasonable estimate for the length 1 of the "string" or the carrier where the pathogenic particle exists is made, then the intensity B of the magnetic field to be applied is specified using equation [1]. Equation [1] is derived as follows. The induced electromotive force (emf) V_i in an electrically conducting carrier (or "string") moving with velocity v through a magnetic field with intensity B is given by Faraday's law.

$$V_i = Bvl \qquad [2]$$

The induced emf V_i is defined as energy E per unit charge, hence,

$$V_i = E/q_j \qquad [3]$$

equating the right hand sides of Equations [2] and [3] and solving for E, we have,

$$E = Bvlq_j \qquad [4]$$

Equation [4] the energy E of the magnetic portion of the electromagnetic interaction in which the force F is expressed in terms of contributions from both electric field E and magnetic field B.

$$F = qE + qv \times B \qquad [5]$$

Neglecting the contribution from E, and expressing the force F in Equation [5] in terms of the energy E, we have,

$$E = q_j l\ (vB\ \sin\theta) \qquad [6]$$

Equation [6] allows any value of angle θ between the direction of B and that of v, whereas Equation [4] applies only for when B is orthogonal to v. Jacobson proposed that it is possible to select B (magnitude of B) and apply the magnetic component of the force whose energy is equal to the specific intrinsic energy mc^2 of any particle by equating the right hand side of Equation [4] with mc^2, arriving at Equation [1]. Assumptions made in deriving Equation [1] are: (i) v and B are orthogonal, (ii) the contribution from electric field E in the Lorentz equation is neglected, (iii) the carrier, or "string" in which the particle exists can be mathematically treated as a one dimensional object, and (iv) the intrinsic energy of any charged particle can be made equal to its energy (product of force and dimension) in an externally applied magnetic field B by selecting the intensity B.

RATIONALE FOR THE VELOCITY V AND STRING DIMENSION 1

For the medical application of Equation [1], one of the authors (JIJ) has chosen the inertial velocity v of the earth as the carrier velocities of biological systems, *i.e.,* the orbital or rotational velocity of the earth. The selection of v depends on the observer's "point of view." An observer with the solar system (or planetary) point of view as one of the authors (JIJ) may choose v as the orbital velocity of the earth, one with the terrestrial point of view may select the rotational velocity. Since the velocity of magnetic fields is c, the interaction between a magnetic field and the material particle is independent of the inertial frame of the earth. The rationale for the unidimensionality of the "string" or carrier is adapted from Einstein, who viewed the largest dimension of all three dimensional objects as the one most closely associated with its velocity.[10]

RELATION TO OTHER RESONANCE PHENOMENA

We consider Equation [1] with respect to other known magnetic resonance phenomena, namely, (a) ion cyclotron resonance, and (b) Zeeman interaction between charged particles and a static magnetic field. Furthermore, we treat the particle in these magnetic interactions as a charged DeBroglie wave particle. We first consider Equation [l] *i.e.,* Jacobson resonance, in relation to the ion cyclotron resonance. When a point mass m with charge q is moving circularly with velocity v and radius r, in a magnetic field of intensity B perpendicular to the plane of the circular motion, the angular frequency of this circulating motion ω_{icr} is

$$\omega_{icr} = v/r = qB/m \qquad [7]$$

The frequency $f = \omega/2\pi$, so that,

$$f_{icr} = v/2\pi r = qB/2\pi m \qquad [8]$$

f_{icr} is known as the ion cyclotron resonance frequency.[11,12]

When r = l, and v = c, the Equation [8] becomes $c/2\pi l = qB/2\pi m$; rearranging and multiply both sides by c we obtain,

$$mc^2 = qcBl \qquad [9]$$

Comparison of Equation [1] and [9] implies that for a charged point mass orbiting (*e.g.,* electron, etc.) with velocity c, with radius l, and $q = q_j$, ion cyclotron resonance and the Jacobson resonance are the same with respect to energy and frequency.

Now, consider the DeBroglie particle wave. A particle of mass m, moving at velocity c, whose momentum p can be expressed by the DeBroglie's wavelength λ, *i.e.*,

$$p = mc = h/\lambda \qquad [10]$$

where h is the Planck's constant. The intrinsic energy E of this particle may be obtained by multiplying both sides of Equation [10] by c, f is the frequency,

$$E = mc^2 = hc/\lambda = hf \qquad [11]$$

Next, we treat this particle wave as a charged particle and place it in an externally applied magnetic field of a selected intensity B, such that the intrinsic energy of this DeBroglie wave particle is equal to the Zeeman resonance energy, *i.e.*,

$$mc^2 = g\beta B \qquad [12]$$

where g is either electron g-factor g_e or nuclear g factor g_n, and β is either Bohr magneton β_e or nuclear magneton β_n. The magneton is generally defined as

$$\beta = qh/4\pi m \qquad [13]$$

and since for the DeBroglie particle, $hf = h/t = mc^2$, and $h = mc^2t$, substituting [13] into [12], the intrinsic energy E becomes

$$E = mc^2 = gqmc^2tB/4\pi m \qquad [14]$$

and dividing both sides by mc^2 and then by t yields the DeBroglie particle wave frequency as

$$f = 1/t = gqB/4\pi m \qquad [15]$$

For the g = 2 particle such as electron, this becomes $f = qB/2\pi m$, which turns out to be the cyclotron resonance frequency. On the other hand, if we just calculate Zeeman resonance frequency, it is,

$$f = E/h = g\beta B/h = gqB/4\pi m \qquad [16]$$

Equations [10] through [16] verify that for a charged particle in the magnetic field, ion cyclotron resonance and Zeeman resonance are the same with respect to particle's intrinsic energy, magnetic resonance energy and frequency. Next, we consider that a charged particle in the Jacobson resonance as a DeBroglie wave particle and calculate its resonance frequency f_{jr} or energy E_{jr} from Equations [1] and [11] we have,

$$f_{jr} = E_{jr}/h = mc^2/h = q_j vBl/h \qquad [17]$$

In general, the particle frequency, the ion cyclotron resonance frequency, and Jacobson resonance frequency are not necessarily the same because of the possible range of the external magnetic field strength B. However, in order for the particle of Equation [1] to resonate with the ion cyclotron resonance frequency it must fulfill the following condition;

$$f_{jr\text{-}icr} = q_j vBl/h = qB/2\pi m \qquad [18]$$

where $f_{jr\text{-}icr}$ is the frequency at which a particle resonates at a single frequency that satisfies both the Jacobson and ion cyclotron resonance equations.

Simplifying Equation [18], and solving for the momentum mv, we arrive,

$$mv = (q/q_j)\ h/2\pi 1 \qquad [19]$$

The condition turns out to be a DeBroglie equation in which the momentum of the particle needs to be equal to $(q/q_j)h/2\pi 1$, where $2\pi 1$ is both the wavelength of that particle ($\lambda = 2\pi 1$) and the circumference of a loop (closed "string") with radius 1. Equation [19] states that the frequency (and energy)

of the Jacobson resonance and ion cyclotron resonance are the same when the above closed "string" or the wavelength condition is satisfied. Looking at the same condition in Equation [19] above in terms of the ratio q/qj,

$$q/q_j = 2\pi mvl/h \qquad [20]$$

or in terms of Bohr magneton β_e, Equation [19] can be rearranged to

$$q_j ml = qh/2\pi m = \beta_e \qquad [21]$$

Conditions under which the energy and frequency of the Jacobson resonance become equal to those of the ion cyclotron resonance include: Equation [8] with v = c, and r = 1, and conditions derived from Equation [18]; Equation [19] for the particle momentum or wavelength, Equation [20] for the charge, and Equation [21] for the electronic or Bohr magneton.

CORRELATION OF THEORY AND NEUROLOGICAL EXPERIMENTS

Cohen measured the magnetic field intensity B of alpha brain waves to be about 1×10^{-9} gauss. He also found that there was a basis for believing that a dc magnetic field of about 5×10^{-8} gauss is associated with delta brain waves.[1] Cohen also measured maximum heart magnetic fields and found them to be about 5×10^{-7} gauss. With the knowledge that very weak magnetic fields, ten million times weaker than the geomagnetic field is produced in the brain, it was possible for Anninos *et. al.* to apply magnetic fields of the similar magnitude to epileptic foci and attenuate seizure activity.[3,4] The field range of 1.2×10^{-7} gauss to 3.0 x 1 gauss and a frequency range of 2-7 Hz were used in pericranial treatment of over 100 epilepsy patients.

For Parkinson's disease patients Sandyk used a 2 Hz, 7×10^{-8} gauss field, applied via a pad containing an array of small diameter coils, placed on patients' crania, and reported that the optomechanically measured tremor of hands and other symptoms were significantly reduced over two weeks.[5]

For multiple sclerosis (MS) patients, the investigator used a 2-7 Hz, 7.5×10^{-8} gauss field and patients showed improvement which was clinically observable and statistically significant.[6] Equation [1] is used in calculating the theoretical values of B. Using these B values and Equation [8] with q and m equal to the electronic charge and mass, it is possible to calculate the theoretical values for ion cyclotron resonance frequency. The values of $v = 3 \times 10^6$ cm/sec, the orbital velocity of the earth, and $l = 1.7 \times 10^2$cm, the average height of the human were used for calculation for B.

For Parkinson's disease, theoretical values $B = 7.5 \times 10^{-8}$ gauss and $f = 2.1$ Hz were obtained with use of $m = 4.25 \times 10^{-20}$ g, the mass of nerve growth factor (NGF).

For MS, $B = 7.8 \times 10^{-8}$ gauss and $f = 2.2$ Hz were obtained with the use of $m = 4.4 \times 10^{-20}$ g, the mass of interferon.

For epilepsy, the low theoretical values $B = 1.2 \times 10^{-8}$ gauss and $f = .34$ Hz were obtained with $m = 6.8 \times 10^{-21}$ g, the mass of the smallest size antigen recognizable by the human immune system.

For the high theoretical values, $B = 8.8 \times 10^{-8}$ gauss and $f = 2.5$ Hz were obtained with $m = 5 \times 10^{-20}$ g, the mass of platelet derived growth factor (PDGF). The comparison of the theoretical B and f with clinical B- and f-values are summarized in Table I.

The B-values are ones reported by aforementioned clinical investigators and are average or mean values over the treated area. These values may contain at least $\pm 0.5 \times 10$ gauss deviations.

Furthermore, in the treatment for Parkinson's disease, it was the investigator's intention to focus the magnetic field to the pineal gland, whereas in the epilepsy study the "feedback" of the reproduced EMG profile near the epileptic foci at the 2-7 Hz band was considered important. For this reason the epilepsy data were expressed in the range of fields instead of single values and may contain high and low values outside of the efficacious therapeutic values. Since the exact etiology of these neurologic disorders is not known, our selection of the molecular species is based upon the incomplete general knowledge of neurologic disease processes in which they are assumed to be closely involved.

Table I
Comparison of Theoretical and Experimentally Determined Magnetic Field Strength B and Frequency f

Disease	Theoretical B (gauss)	f (Hz)	EXP 1 B (gauss)	f (Hz)
Parkinson	7.5×10^{-8}	2.1	7.0×10^{-8}	2.0
MS	7.8×10^{-8}	2.2	7.5×10^{-8}	2-7
Epilepsy	1.2×10^{-8}(L)	0.34(L)	0.3×10^{-8}	2-7
	8.8×10^{-8}(H)	2.5(H)	12×10^{-3}	2-7

OTHER CORRELATIONS

In addition to the agreement between the theoretical (Equation [1]),[8] and experimental magnetic field B-values and frequency f-values used in clinical neurological trials, we found that other studies which may not report beneficial effects correlate with the theoretical B and f-values. Specifically, the f-value used by Goodman *et. al.* who demonstrated that human leukemia cells (HL60) exposed to ELF electromagnetic field exhibited significant changes in their gene transcription, RNA synthesis, translation, and protein synthesis.[13-16] One of the frequencies of major interest in Goodman's work f = 60 Hz, that of household and industrial AC electricity, can be predicted from Equation [8] with $q/2\pi m = 7.6 \times 10^{2}$ coulomb g^{-1} and $B = 8.0 \times 10^{-1}$ gauss. The B-value and the intrinsic/Lorentz energy value of 144 ergs is predicted from Equation [1] with oncogenic mass $m = 1.6 \times 10^{-19}$g, earth's orbital velocity $v = 3 \times 10^{-4}$cm sec^{-1}, and cellular diameter $l = 6 \times 10^{-4}$ cm. In the same context Equation [1] also predicts a growth factor of mass $m = 4 \times 10^{-20}$ g in a virus with length $l = 2.4 \times 10^{-5}$ cm that will resonate at the intrinsic/Jacobson energy of 36 ergs.

TRIAL B- AND F-VALUES FOR POSSIBLE MAGNETIC THERAPY

Although Anninos, *et. al.* and Sandyk's data are, at this time, the only clinical data that were compared with Equation [1], it is of interest to predict the specific B-values computed from Equation [1], and f-values from Equation [8] for other diseases/disorders of unknown or vague etiology. One can calculate several trial values of B- and f-values computed from the mass m of the known, documented, or or suspected pathogens, or related molecular species which are closely associated to a specific disorder/disease process. These trial values should subsequently be tested experimentally for their efficacy. For example, for one of the possible treatments of AIDS, the mass of the envelop protein of the HIV, $m = 6.85 \times 10^{-20}$ g[17], is used to obtain $B = 1.2 \times 10^{-7}$ gauss and $f = 3.38$ Hz. For a treatment of multiple myeloma, the mass of Bens Jones protein, $m = 7 \times 10^{-20}$ g[9], may be used to obtain $B = 1.2 \times 10^{-7}$ gauss and $f = 3.50$ Hz.

SUMMARY

The intensity B of the externally applied magnetic field B and frequency f used in the recent successful clinical trials utilizing extremely weak (in picoTesla range) magnetic fields to treat patients with Parkinson's disease, epilepsy, and multiple sclerosis were correctly predicted from the Jacobson and ion cyclotron resonance equations (Equations [1] and [8] respectively). The former is used to predict the B-values of possible therapeutic efficacy, from the known mass m of a molecular species suspected to be involved in the disease process. The latter was determined for the f-values of possible therapeutic efficacy, from the known mass m and B-values calculated with the use of Equation [1]. We conclude that the physical mechanism operative in the magneto therapy of neurological and other disorders includes both Jacobson and ion cyclotron resonance (or Zeeman resonance). The Jacobson resonance is used to predict B-values for any particle (including pathogenic particles), placed in an external magnetic field B, whereas the ion cyclotron resonance is used for predicting f-values of the charged ionic species (electrons, protons, Na^+, K^+, Ca^{+2}, PO^{+3}, etc.) placed in an external magnetic field B. For many

pathogenic or pathology related particles (molecular species), the B-value turns out to be in extremely weak picoTesla range, and the f-value in the extremely low frequency (ELF) range. There are no criteria inherent in either theory for determining whether the effect of magnetic field on biological systems is beneficial or hazardous.

DISCUSSION

The clinical data such as restoration to normal, after treatment (EMG profile), improved clinical symptoms, and laboratory analysis of blood and sera need to be correlated with changes in molecular structure, conformation, and other molecular, cellular, or histological properties resulting from the exposure to the picoTesla magnetic field. The following remain to be determined: (i) the specific nature of the molecular, cellular, or histological changes, (ii) the evidence that magnetically induced photons can cause such molecular or microscopic changes, and (iii) the effects of such initial molecular, macromolecular, or microbiological changes on the known biochemical pathways of human endocrinology, immunology, and genetics, and (iv) the experimental determination of the criteria separating beneficial from hazardous or undesirable magnetic field effects.

The fundamental concept implicit in Equation [1] (*i.e.*, assumption (iv) on page 242) is Einstein's view that gravitational ether exists, and participates in the motion of ordinary matter. In addition it provides the medium for electromagnetic fields. He stated that every day reality compels us to believe that the causal linking of natural phenomena involves the communication of motion through impact or contact.[14] The Kalusa-Kline theory assigned a fifth coordinate for gravity in unifying gravity with electromagnetism.[15] Supersymmetry and superstring theoreticians accomplished a similar abstract mathematical unification by proposing the concept of shadow-matter (or dark matter) and several additional dimensions.[16,17] The Newtonian action at a distance concepts which do not account for the force carrier in free space were not accepted by either Einstein or modern theoreticians.

Further theoretical details which need to be addressed include: magnetic anisotropies typical in crystalline and liquid crystalline materials, magnetic

interactions such as Fermi contact (or electron nuclear hyperfine interactions) in free radicals, electron dipole-dipole interactions in the photo-excited triplet states and stable paired radicals, or electron spin orbit (Russel-Saunders) coupling in organo-transition metal complexes. All of these magnetic interactions further split the Zeeman energy levels into several discreet energy levels. Spin-orbit and electron dipole-dipole interactions exist at zero applied field and hence the pathogenic particles that may contain these interactions may require corrections arising from these additional magnetic interaction terms (Hamiltonians).

Another important consideration is that the MEG profile of a normal individual may vary depending on the state of his mind. The MEG profiles corresponding to the alpha waves, and those corresponding to the theta waves are expected to be different. What constitutes the normal MEG profile? Is the efficacy of magneto-therapy distinguishable from the psychological effect of the patients on receiving a therapy? Future clinical studies should be designed to answer some of these questions.

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