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Magnetic Healing, Quackery, and the Debate about the Health Effects of Electromagnetic Fields

1. Roger M. Macklis, MD

Author Affiliations
From Harvard Medical School, Boston, Massachusetts. ***Requests for Reprints:*** *Roger M. Macklis, MD, Harvard Joint Center for Radiation Therapy, 50 Binney Street, Boston, MA 02115.*
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Abstract

Although the biological effects of low-frequency electromagnetic radiation have been studied since the time of Paracelsus, there is still no consensus on whether these effects are physiologically significant. The recent discovery of deposits of magnetite within the human brain as well as recent, highly publicized tort litigation charging adverse effects after exposure to magnetic fields has rekindled the debate. New data suggest that electromagnetic radiation generated from power lines may lead to physiologic effects with potentially dangerous results. Whether these effects are important enough to produce major epidemiologic consequences remains to be established. The assumption of quackery that has attended this subject since the time of Mesmer's original “animal magnetism” investigations continues to hamper efforts to compile a reliable data base on the health effects of electromagnetic fields.

In January 1992, lawyers for a 21-year-old Connecticut woman who had a malignant brain tumor filed the first widely recognized and authoritatively researched U.S. lawsuit charging that the tumor was the direct result of the patient's protracted exposure to the electromagnetic field (EMF) generated in a nearby power line [1]. This case and other similar tort cases are being based in part on new suggestive evidence for adverse EMF bioeffects [2]. Well-known investigators in the field have recently published position papers on both sides of the EMF bioeffects problem [3, 4]. Both sides apparently agree that the debate has been hampered by the lack of a biochemical transduction mechanism capable of explaining how low-energy magnetic fields interact with human tissue [5].

If confirmed, the recent discovery by Kirschvink and colleagues [6] of substantial deposits of elemental magnetite in human brain tissue may finally provide a mechanistic framework within which to analyze the epidemiologic and toxicologic data concerning EMF bioeffects. However, the sensational media coverage accorded the neural magnetite discovery and the instant skepticism and partisan hostility engendered by the magnetite announcement reflect the fact that the EMF bioeffects problem continues to be surrounded by an aura of pseudoscience, quackery, and disrepute [7-9].
This article traces the history of biomagnetism and magnetic healing, concentrating on the charlatanism and quackery that have plagued the field for centuries and that may now be limiting legitimate scientific investigation by placing the field off-limits to respectable medical investigators.

The History of Biomagnetism

For more than 2000 years, the effects of magnets and low-frequency electromagnetic fields on biological processes have been investigated and debated [10, 11]. The term “magnet” was probably derived from Magnes, a shepherd who discovered mysterious iron deposits attracted to the nails of his sandals while he was walking in an area near Mount Ida in Turkey (“Magnesia”) [11]. These deposits, now known to be magnetite (magnetic oxide, Fe_{3O4}), were known to the ancients as “Heraclean Stones,” lodestones (“leading stones”), or live-stones (lapis vivus).

Plato claimed that it was Euripides who first coined the term “magnet” and who attributed magnetic force to a kind of mineral soul within the stone [12]. Pliny the Elder recorded several examples of the potential use of these lodestones, such as the plans of the Macedonian architect Deinokrates to build a huge, magnetically levitating statue for Ptolemy II of Egypt [11]. Literary allusions to magnetism are found in the works of Chaucer, Bacon, and Shakespeare, who refer to magnets as “adamants” or “adamaunds,” from the Latin “adamare” meaning to be drawn to something through instinctive attraction and love [12]. These writers and their contemporaries assumed that the static electric attraction of nonferrous materials including hair or cloth to amber was also an example of the power and the mineral soul possessed by “magnetic” substances.

Medieval Investigations: Medicinal Magnetism

Peter Peregrinus is credited with writing the first major postclassical discourse on magnetism in 1289, describing in great detail the principles and use of the magnetic compass [13]. Medieval writers thought that magnets were capable of drawing “the heart of a man out of his bodie without offending any part of him,” and scholars believed magnets were causes and cures for melancholy [12]. Lodestones were thought to have strong aphrodisiac powers based on “magnetic” human attraction; magnetic “cures” for diseases such as gout, arthritis, poisoning, and baldness are documented in many medieval works [11]. More legitimate medieval applications included the use of magnets as probes and retrieval devices for shattered arrowheads, knife blades, and other iron foreign bodies [14].

Several important studies occurred in the 16th and 17th centuries. The Swiss physician, philosopher, and alchemist Paracelsus (1493-1542) investigated the medical properties of lodestones in the treatment of diseases such as epilepsy, diarrhea, and hemorrhage [7, 11]. William Gilbert (1544-1603), physician to Queen Elizabeth I, wrote his classic text De Magnete in 1600 [15], describing hundreds of detailed experiments on electricity and terrestrial magnetism and debunking many quack medicinal uses of the magnet. Thomas Browne (1605-1682) continued this attack on popular magnetic salves and remedies, suggesting that their putative healing power was due only to incorporated herbal and mineral compounds [11]. The 17th century physician Kirches (1602-1680) developed a magnetic cure for strangulated hernias in which the patient was first fed iron filings and the imprisoned intestine was then freed from the surrounding muscular sheath through the external application of powerful magnets [12]. In a similar manner, magnets were used by early oculists to retrieve iron splinters from the eyes of blacksmiths and other metal workers.

Animal Magnetism and the Rise of Magnetic Quackery

By the middle of the 18th century, durable high-power magnets were available throughout Europe. Among the European researchers who began to investigate the medical powers of these magnets was the Czechoslavakian-born Jesuit Maximillian Hell [16], chief astronomer at the University of Vienna and a respected experimentalist who published a treatise on magnetism in 1762 [17, 18]. Though Father Hell's professional duties prevented him from spending much time developing his magnetic theories, he did manage to interest one of his younger university colleagues in the field. This young man was Franz Anton Mesmer (1734-1815), a brilliant and iconoclastic young intellectual trained in mathematics, medicine, and law who was known for his quick mind, stylish clothes,

theatrical demeanor, and riveting gaze (Figure 1). The young Mesmer's doctoral thesis, “Dissertatio physicomedice de planetarum influxu” (1766), dealt with the effects of gravitational fields and cycles on human health and was extensively influenced by the writings of Paracelsus and the work of Richard Mead [19, 20]. Over the next several years, Mesmer refined his theories and eventually suggested that gravitational forces might interact with the human body in such a way as to produce a sort of sympathetic magnetic flux capable of profound neuropsychiatric and constitutional effects. He called this process “animal magnetism” (“magnetisonum animalem”) and felt that he had stumbled upon a fundamental biophysical force analogous to gravity [20, 21].

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Figure 1. The self-proclaimed discoverer of “animal magnetism,” depicted at age 44 years. Franz Anton Mesmer.

During the early 1770s, the young Mesmer began a medical practice among the prosperous salon society of Vienna, becoming friendly with many Austrian court musicians and artists including W. A. Mozart [18]. Mesmer was especially interested in neuropsychiatric syndromes and intractable emotional problems, and he continued to believe that biophysical phenomena might be responsible for some aspects of these illnesses [21]. To investigate this possibility, Mesmer and some colleagues (including a Swabian mystic named J. J. Gassner) quietly began to conduct preliminary clinical investigations in 1774. In 1775, at the age of 41, Mesmer published his first major medical treatise in the form of an open letter to a foreign correspondent, Dr. J. C. Unzer, entitled “On the medicinal uses of the magnet” [20].

Clinical Treatment

This letter recounts the clinical details of his treatment of an unnamed, young female patient (later identified as a distant relative named Francisca Oesterlin) who had episodic convulsions and hysteria. In his journals, Mesmer noted that, before his treatment, she had mysterious attacks of uncontrolled and apparently unprovoked vomiting, urinary retention, toothaches, opisthotonus, blindness, melancholy, and paralysis [22]. Mesmer believed that he could discern a fixed periodicity in the timing of some of these attacks, and, based on his previous theories concerning gravitational and magnetic interactions, he resolved to attempt to cure her by means of a magnetic counterflux (“a kind of artificial tide produced by means of a magnet”) [20]. This magnetotherapy was aimed at breaking the influence of a celestial force that Mesmer believed was interfering with the natural magnetic harmony of Oesterlin's body.

Mesmer obtained some anatomically contoured steel magnets from his astronomic colleague Father Hell, and on 28 July 1774, Mesmer did his pioneering clinical experiment. He attempted to interrupt the cycle of Oesterlin's attacks by first having the patient swallow an iron-rich solution and then attaching conformal magnetic soles to each of her feet and a heart-shaped magnet to her chest. His notes describe the effects of this magnetic counterflux.

She soon underwent a burning and piercing pain which climbed from her feet to the crest of the hip bone, where it was united with a similar pain that descended from one side-from the locality of the magnet attached to her chest-and climbed again to the other side where it ended at the crown … This transport of pain lasted all night and was accompanied by abundant sweating of the side paralyzed by the former attack. Finally, (her) symptoms disappeared … [20].

Mesmer felt that these effects were more dramatic than could be expected based on his earlier work with simple terrestrial magnets. Instead, he postulated that another, more mysterious type of "universal" magnetic force was responsible for Oesterlin's recovery. Mesmer proposed that this secondary force derived from his own highly advanced psychic abilities as a conduit and focuser of the magnetic flux [22]. Downplaying the therapeutic importance of Hell's steel magnets, Mesmer ascribed Oesterlin's cure to the successful manipulation of a universally permeating ("fluid-like") biophysical flux (analogous to other post-Newtonian theories of matter/force interactions) capable of influencing virtually all physiologic processes [20]. In experienced hands, this flux could be directed to exact physiomagnetic pressure points and its effects reinforced by psychological amplification.

Mesmer used the term "animal magnetism" to describe these forces, because he believed that the therapeutic basis of the approach involved the re-establishment of the normal state of physiologic synchrony and magnetic polarity in organs that had somehow become misaligned. The re-establishment of magnetic harmony was generally preceded, Mesmer believed, by a physiologic and psychological "magnetic crisis" characterized by the sort of incoherent speech, bizarre behavior, and loss of consciousness observed in Oesterlin. After the successful re-induction of magnetic harmony, the repolarized patient awoke with only a vague memory of what had transpired. In retrospect, it is clear that Mesmer had discovered hypnotism [21], and his seminal role in hypnotism and psychoanalysis has been immortalized in the popular term "mesmerize".

Animal Magnetism

Investigations of animal magnetism, or "Mesmerism" as it was later called, became astonishingly popular throughout the salons of Europe [23]. Under pressure from the Viennese Faculty of Medicine, who disapproved of his doctrines and their spiritualistic overtones, Mesmer moved to Paris in 1777. His private clinic in the exclusive Place Vendome section of the city soon acquired a reputation for spectacular therapeutic sessions that combined magnetic paraphernalia, high drama, and rooms full of fainting patients experiencing sensual release and emotional catharsis.

In the centre of the saloon was placed an oval vessel, about four feet in its longest diameter and one foot deep. filled with magnetized water. called the baquet. From each hole (in the baquet) issued a long movable rod of iron, which patients were to apply to such parts of their bodies as were afflicted. Then came the assistant magnetizers, generally strong, handsome young men, to pour into the patient from their fingertips fresh streams of the wonderous fluid. They embraced the patients between the knees, rubbed them gently down the spine and the course of the nerves, using gentle pressure upon the breasts of the ladies, and staring them out of countenance to magnetize them by eye. All this time the most rigorous silence was maintained, with the exception of a few wild notes on the (glass) harmonica [24]..

Mesmer's claim that animal magnetism was a classical Newtonian force similar to gravity was eventually debunked by a special study panel convened by the Royal French Academy of Science in 1784. This panel included Antoine Lavoisier, J. I. Guillotin (popularizer of the decapitation device), and Benjamin Franklin. In a controlled set of blinded experiments in which patients were exposed alternately to a series of magnetic or sham-magnetic objects and were asked to describe their sensations, the committee decided that the efficacy of the magnetic healing seemed to reside entirely within the mind of the patient [25]. Interestingly, Mesmer himself refused to participate in these trials. Mesmer instead asked that patients with refractory neuropsychiatric illness be randomly treated either by his technique or by the best medical techniques of the academy panel and he asked that the patients themselves decide who were the charlatans. The panel refused, acknowledging that they did not discount the possible benefits of Mesmeric therapy, simply its basis as an objective biophysical force. Animal magnetism, the panel decided, owed its apparent efficacy to the power of suggestion in susceptible or naive individuals [26].

Electromedicine and Magnetic Tractors

Although in France Mesmerism soon came to symbolize the worst aspects of medical quackery, elsewhere in the world clinical research in the field continued unabated [27]. The widespread academic skepticism that occurred after the French Royal Panel gave its report on animal magnetism does not appear to have lessened the public's enthusiasm for the application of electromagnetic radiation in the treatment of illness. One contemporary of Mesmer's, P. J. C. Mauduyt de la Verenne, whose investigations of electrical medicine underwent the same hostile scrutiny as Mesmerism, was able to contrast the “objective” nature of electricity and its (often painful) physiologic effects with the more subjective nature of Mesmer's animal magnetism [28]. Riding on the coat-tail of the animal magnetism movement, electromedicine flourished briefly in Europe and America. Franklin himself was involved in experiments in which electric discharges (originally from electric stinging fish) were used in the treatment of epilepsy [18].

By 1795, a Connecticut physician and sometime mule trader named Elisha Perkins had developed a therapeutic device based on a set of principles that were a synthesis of animal magnetism and electromedicine [29]. This device, called a “magnetic attractor” or simply “tractor,” was in fact a plain pair of small metal wedges made from a series of alloys (copper/zinc/gold and iron/silver/platinum were popular combinations) that Perkins claimed could “draw off the noxious electrical fluid that lay at the root of suffering” Figure 2[29]. Based on testimonial evidence from satisfied customers, Perkins was awarded a patent from the U.S. government and became wealthy selling his tractors for $25/pair. Despite charges from the Connecticut Medical Society that his device was merely “gleaned up from the miserable remains of animal magnetism,” Elisha Perkins and his son Benjamin (who acquired a British patent for the tractors based on an application entitled “Application of galvanism as a curative agent”) succeeded in giving the metallic tractors the reputation as one of the great therapeutic marvels of turn-of-the-century medicine [29]. Attempts by the medical establishment in America and in Europe to discredit the physiologic basis of the metallic tractor therapies were met with charges of physician greed, professional arrogance, and deliberate restriction of “alternative” health care approaches [30].

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Figure 2. Original engraving is in the National Library of Medicine, Bethesda, Maryland; reproduced from reference 62. Caricature of Elisha Perkins' treatment approach by James Gillray (1801) entitled “Metallic Tractors”.

Unfortunately for Perkins, the powers of the metallic tractors proved insufficient to protect their inventor from the East Coast yellow fever attack of 1799. Perkins rented a boarding room to practice his metallic tractor therapy among the poor of New York City, contracted yellow fever, and promptly died. Nevertheless, electromedicine was by then well established, and Perkins' death did not appreciably dampen the grassroots enthusiasm for the use of electromagnetic approaches to the treatment of many different diseases. So common were these sorts of devices that the 19th century has been referred to as the “electromagnetic era of medical quackery [31]”.

Meanwhile, the therapeutic application of natural, artificial, and “psychic” magnetic fields to patients with supposed disturbances in their polar equilibria continued to develop. Hans Christian Oersted showed in 1820 that a magnetized needle was deflected by an electric current, thus definitively linking electric and magnetic forces. During the mid-1800s, Michael Faraday in England

and Joseph Henry in America were responsible for a series of brilliant conceptual advances in the understanding of electromagnetism and its practical applications [11]. Electromagnetic turbine technology provided the promise of virtually limitless power; this excited the public, who clamored for further research into the potential "humanistic" uses of magnetism. A widely disseminated pamphlet published by the Massachusetts preacher Reverend Jacob Baker in 1843 entitled "Human Magnetism" stated that an ether called "nervo-vital fluid" pervaded all natural objects, producing such physical forces as electricity, magnetism, and galvanism and serving as "the great connecting link between mind and matter [32]". When mobilized by force of will or by a strong external magnetic field, Baker claimed, this nervo-vital fluid was capable of producing anesthesia, levitation, and cure of such diseases as asthma, epilepsy, neurasthenia, blindness, and cancer.

Magnetic Shields and Electromedicine

Nowhere in post-Civil War America was public interest in electromedicine and magnetic healing more widespread than in the newly industrialized farm belts of the Midwest. Perhaps indicative of the relative scarcity of well-trained physicians and the history of self-doctoring in the Midwest, this area seems to have been fertile ground for a number of electroquacks who extolled the curative powers of protracted exposure to electric and magnetic fields [7]. The Sears Roebuck mail-order catalog, a useful indicator of mid-American social trends, proudly hawked what it claimed were the first genuine electric health rings and advertised magnetic boot insoles for 18c/pair. Various brands of supposedly "magnetic" salves and liniments were available over the counter and were dispensed by traveling magnetic healers [33].

Chief among the magnetic healers of this period was a tall silver-tongued mountebank named Dr. C. J. Thacher (Figure 3). A journalist who went to interview Thacher in his State Street office in downtown Chicago found him wearing a magnetic cap, a magnetic waistcoat, magnetic stocking liners, and magnetic insoles. This comical appearance belied Thacher's apparently heartfelt conviction that magnetotherapy could cure virtually all chronic diseases and that the medical establishment was engaged in a cynical as well as unethical attempt to restrict the use of this "natural" panacea. Thacher willingly shared his philosophy with the reporter.

My object is to spread the light, to rescue humanity. I can cure anything. In time I will compel the authorities to take notice of my methods … .Let the authorities turn over ten cases to me. I'll put my magnetic shields on 'em and restore the harmonious vibrations of the brain, and everything will be well! Paralysis? An easy problem. Had five cases … .Cured 'em right off. Winked. Spoke. Got up and walked. Paralysis? Pish! [33].

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Figure 3. C. J. Thacher, president of the Chicago Magnet Company. He was dubbed the "King of the magnetic quacks" by Collier's Magazine. Dr.

A mail-order pamphlet printed in 1886 and distributed by Thacher's Chicago Magnetic Company explained how magnetic healing provided a "plain road to health without the use of medicine. The vigor of life in plant, animal and man," notes the pamphlet, "is thus almost entirely dependent upon the magnetic energy of the sun [34]".

According to the magnetic healing doctrines, the copious iron content of the blood made it the primary magnetic conductor of the body. Disease resulted, practitioners claimed, when the blood's natural ability to siphon magnetic power from the atmosphere was compromised by unhealthy living. The most efficient way to recharge the blood's magnetic field was through the use of magnetic garments, and Thacher's Chicago Magnetic Company produced a full line of these garments. The complete set (containing over 700 individual magnets) was said to "furnish full and complete protection of all the vital organs of the body". Thacher's literature includes dozens of testimonial letters affirming the worth of the magnetic clothing and enthusiastically endorsing Thacher's contention that "magnetism properly applied will cure every curable disease no matter what the cause [34]".

By the late 19th century, the medical establishment was beginning to accept the role of electromagnetic approaches to the treatment of some diseases, though the concept was still considered controversial. A standard medical textbook from the period devotes an entire chapter to the use of galvanism and electromagnetic fields in the treatment of neurologic disease [35]. In Robert Bartholow's 1887 textbook, Medical Electricity, the author reports [36] that magnetic fields applied to the skin resulted in the production of both magnetic and induced currents, leading to "very extensive subjective impressions of heightened organic activity … .These results were so uniform that there seemed to be no doubt of their genuineness".

Other investigators were less impressed. Blinded, controlled experiments conducted at the turn of the century by experts such as Professor Bertram Windle of Mason College [37] and Mr. A. E. Kennelly, chief electrician at the Edison Laboratory [38], using newly available high-strength terrestrial and artificial electromagnets, suggested that minimal, if any, physiologic consequences existed even after exposure of a volunteer to a magnetic field 27 000 times more powerful than that of the earth. These contradictory data made it difficult for the medical establishment to either restrict or condone the practice of magnetic healing. Thus, the sale of magnetic therapy devices was essentially unregulated [31].

Electromedicine

By the early 20th century, electrotherapeutics was considered a legitimate medical subspecialty, often practiced in conjunction with the rapidly expanding "glamour" fields of radiology and radium therapy. Though some practitioners were legitimate, others were clearly confidence men cashing in on the public's perennial fascination with high-technology medicine. Perhaps the greatest exemplar of this latter group was Dr. Albert Abrams Figure 4, the man whom the American Medical Association referred to as the "Dean of 20th-century charlatans [1, 31]". Abram's medical contraptions, with engaging high-technology names such as the "dynamizer" and the "oscilloclast," were all based on his "radionic" theory of physiologic frequency manipulation [39, 40]. This theory postulated that each organ system and each patient were "tuned" to characteristic electromagnetic wavelengths. Proponents of this theory claimed that radio-based devices tuned to the proper frequency could diagnose and even deliver treatment to individuals located thousands of miles away. Abrams died in 1924 (leaving an estate of several million dollars), but the public continued to show an intense fascination with electromagnetic physiologic effects. Mainstream medical investigators, in contrast, began to lose interest in bioelectricity; however, major current clinical applications such as electroconvulsive therapy, cardioversion, and transcutaneous nerve stimulation can be traced back to initial work done during the bioelectricity heyday at the turn of the century [36].

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Figure 4. Albert Abrams (1863-1924) with one of his electric frequency modulating machines. Original photo from the San Francisco Public Library; reproduced from reference 7. Dr.

An Index Medicus survey suggests that, by the time of the second World War (when long-distance power lines had been in place and safely used for more than a decade), the physiologic effects of electromagnetic fields were no longer receiving much attention in academic medical journals. It was estimated that even in heavily industrialized areas, most domestic EMFs amounted to only a few milligauss, about 1% of the ambient terrestrial magnetic field. A small cadre of dedicated investigators and hobbyists continued to experiment on the potential electromagnetic basis of such diverse phenomena as mutagenesis, lifespan extension, water dowsing, embryology, immunologic tolerance, magnetotropism, wound healing, and neurologic function, but for the most part these were small, poorly controlled studies [41]. Barnothy reviewed [42] all the available data in the 1960s, publishing a comprehensive two-volume summary on the biological effects of magnetic fields. Although much of this early work now appears questionable, some of the in vitro studies indicate that, at least at the cellular level, strong magnetic fields may indeed have subtle physiologic consequences. Nevertheless, most mainstream investigators assumed that these effects would be trivial when analyzed on an organismal level.

Biomagnetism Reconsidered: The Electromagnetic Field-Cancer Connection

Interest in the health effects of low-frequency EMFs was rekindled by a series of epidemiologic studies done during the late 1970s and early 1980s [43]. Milham analyzed [44] the occupational grouping of cancer deaths in 438 000 adult white men who died in the state of Washington between 1950 and 1979. Of the 11 occupational groups expected to have above-average EMF exposure, 10 had an increased proportionate mortality ratio for leukemia. Although this EMF-leukemia connection was not apparent in a number of other epidemiologic datasets examined, studies by McDowall, Wright, and others did suggest a small but significant relation between occupational EMF exposure and leukemogenesis [5]. Other studies in adults have suggested increased occupationally associated EMF risks for male breast cancer, abnormal pregnancies, chromosomal abnormalities, congenital deformities, and several other health hazards [10]. Many of these occupational studies have been attacked on the basis of faulty methods or questionable statistical significance. It seems fair to say that the purported increases in health risks associated with adult occupational exposure to power-frequency EMFs, even if verified, are likely to be insignificant compared with other health risks prevalent in an industrialized society [10, 45].

The data for adverse childhood EMF bioeffects (primarily cancer induction) are not so easily dismissed [46]. For children, EMF exposure must be assumed to be domestic rather than occupational, and a number of important studies have concluded that a small but clinically significant relation does exist between leukemia risk and the wiring configuration of a child's home

[41]. Wertheimer and Leeper [47] originally reported that children from high EMF-exposure homes were 2 to 3 times as likely to develop cancer (especially leukemia, lymphoma, and brain tumors) than children from low EMF homes. However, this study was widely attacked on the basis of unblinded design and estimated rather than measured domestic EMF exposure. Savitz and colleagues [48] did a more rigorous case–control analysis on EMF exposure and childhood cancer in the Denver area between 1976 and 1983, they reported a lower but still significant risk ratio of about 1.5 for high-EMF environments.

Other studies have also concluded that high domestic EMF exposures confer an increased odds ratio of approximately 1.2 to 2.0 for the development of childhood leukemia, but the confidence intervals on most of these studies are too broad to allow definitive conclusions to be drawn [5]. Nevertheless, the general concordance of the results from many separate studies of putative EMF-induced carcinogenesis has caused many epidemiologic investigators to rethink the EMF problem. As Florig has noted [45], even if this small increased risk of carcinogenesis is real, the excess cancer mortality associated with high EMF exposure (estimated at 5 deaths per 100 000 population per year) would be similar to other known carcinogenic risks, including in-utero exposure to diagnostic X-rays, and the risk would thus lie above the generally accepted thresholds for active risk reduction and national regulatory attention.

Why are the data for low-dose fetal radiation carcinogenesis readily accepted and the equally compelling data for EMF carcinogenesis dismissed and attacked? Foster [5] has commented that, unlike most known carcinogenic risk factors (which are known to produce DNA damage), EMF bioeffects are not yet scientifically “anchored” to a set of testable hypotheses concerning molecular damage and cellular EMF transduction mechanisms. Risk analysis of EMF is still conducted primarily at the level of phenomena rather than of molecular analysis. This is not, however, because no biochemical effects have been reported. Such known cellular control mechanisms as cell-cell signaling [49], protein expression patterns [50], calcium homeostasis [51], inflammation and immune system function [52], and DNA synthesis [53] are all reportedly affected by EMF exposure in experimental systems. The problem, it appears, is that most of these studies are preliminary and have not yet been confirmed on a wide enough scale to galvanize scientific opinion. This may be primarily because, in an age of molecular medicine, the number of biochemically trained, nonpartisan investigators in the EMF field remains small. Foster [5] has noted that a fundamental requirement of a good mechanistic theory in epidemiologic hazard analysis is the ability to use the theory to predict who will ultimately be afflicted by the hazard. For the EMF health effects problem, no theory has met this test of utility.

Does a Tradition of Quackery Impede Medical Inquiry?

Why have there not been more rigorous biochemical investigations into the EMF bioeffects problem? This problem is historical and relates to the fact that recent academic EMF work has been done by those involved in the relatively new field of molecular epidemiology, an area just beginning to recruit large numbers of well-trained investigators. Unlike ionizing radiation, which can readily be shown to produce DNA strand-break damage and mutations, even relatively intense power-frequency EMFs do not appear to show this direct method of clonogenic cellular damage, thus negating the paradigm that has been established for investigating carcinogenic substances [54]. Although other mechanisms for EMF-induced bioeffects are certainly plausible [55], the investigation of these postulated mechanisms requires a certain leap of faith by the investigative community, and it is possible that the long tradition of intertwined science and charlatanism in the EMF field may prevent many mainstream investigators from gambling their academic reputations on these novel concepts.

Wary of media sensationalism and public attention, legitimate scientists may immediately react to such “hot” topics with skepticism and denial, especially when the subject has a history of associated charlatanism [56]. Like alchemy and parapsychology, EMF bioeffect analysis may now be viewed as tainted and unfit for legitimate investigation. Badash [57] and others have noted that some areas of scientific investigation appear to strike an immediate responsive chord with the lay public and the media as well as cause a resulting ripple effect (first positive then negative) within the scientific establishment. Indeed, the EMF debate has some interesting parallels with the debate on the health consequences of ionizing radiation that took place in the early decades of this century [58].

Many well-respected investigators would argue that it is now time for the scientific community to re-examine the EMF problem in a careful, dispassionate way. In contrast to previous eras, many of the epidemiologic attempts now underway to validate hypotheses about EMF health effects are making use of good, well-controlled, statistically valid experimental models and are being conducted by serious, mainstream scientists [59, 60]. Current laboratory investigations make use of more sophisticated techniques and instruments than were available in earlier periods. The ongoing investigation of magnetic resonance patterns in tissues may provide the basis for an understanding of the EMF effects at the cellular and molecular level. Moreover, experimental methods and standards of proof in medicine and risk analysis are now more sophisticated and more universally accepted than was the case when many of the earlier experiments were done, and modern studies may elucidate even subtle, nonlinear, and delayed effects. It will be interesting to observe whether the new, more authoritative investigations of EMF bioeffects currently being done are perceived with the sort of open-minded appraisal expected of scientific inquiries or whether they will continue to be consigned to the level of “fringe” science [61]. As William Gilbert noted [15] in his preface to De Magnete, “In the discovery of secret things and in the investigation of hidden causes, stronger reasons are obtained from sure experiments and demonstrated arguments than from probable conjecture and the opinions of philosophical speculators … .”.

Abbreviation

EMF: electromagnetic field

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