

Headaches from Cellular Telephones: Are They Real and What Are the Implications?

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There have been numerous recent reports of headaches occurring in association with the use of hand-held cellular telephones. Are these reported headaches real? Are they due to emissions from telephones? There is reason to believe that the answer is “yes” to both questions. There are several lines of evidence to support this conclusion. First, headaches as a consequence of exposure to low intensity microwaves were reported in the literature 30 years ago. These were observed during the course of microwave hearing research before there were cellular telephones. Second, the blood–brain barrier appears to be involved in headaches, and low intensity microwave energy exposure affects the barrier. Third, the dopamine–opiate systems of the brain appear to be involved in headaches, and low intensity electromagnetic energy exposure affects those systems. In all three lines of research, the microwave energy used was approximately the same—in frequencies, modulations, and incident energies—as those emitted by present day cellular telephones. Could the current reports of headaches be the canary in the coal mine, warning of biologically significant effects? *Key words:* brain, cellular telephones, electromagnetic fields, eye, hazards, headaches. *Environ Health Perspect* 106:101–103 (1998). [Online 23 January 1998] <http://ehpnet1.niehs.nih.gov/docs/1998/106p101-103frey/abstract.html>

There have been many recent reports of headaches occurring in association with the use of hand-held cellular telephones (1,2). Digital telephone users are more likely than analog telephone users to report headaches. Are these reported headaches real? Are they due to emissions from the telephones? There is reason to believe that the answer is “yes” to both questions.

There are several lines of evidence to support this conclusion, evidence that was gathered in the 1960s and 1970s, well before there were cellular telephone systems. The evidence from that research now has unsettling implications because of the recent development and now widespread use of cellular telephones.

At that time, it was reported that when people are exposed to very low intensity microwave energy with certain frequency and modulation characteristics, they report that they hear sounds (3,4). This has been called the microwave hearing effect. These sounds, e.g., buzzes, clicks, tones, etc., vary as a function of the modulation. The incident average power density at the head needed to induce the effect is quite low, in microwatts per square centimeter. The transmitting antenna can be many feet away.

The salient characteristics of the primary cellular telephone systems in use today are shown in Table 1. The transmitting frequencies fall in the most sensitive band for the microwave hearing effect (5). The transmitting frequencies are also in the band that has maximal penetration into the head (4). Further, when the head is shielded from the microwave energy, the area of the head that needs to be exposed to the microwaves in order for people to perceive the effect is in proximity to the antenna of present day cellular telephones (4).

In a series of experiments, the microwave hearing effect apparently occurred within the cochlea (6–9). (There is some confusion in the literature because a few people, using high power energy delivered by applicators placed on the head, induced vibration in the head; they called this microwave hearing, but it is a different phenomena.) Microwave hearing is a robust effect. Puranen and Jokela (10), for example, stated in a recent review that “...the microwave auditory effect is the only well established specific effect in realistic exposure situations.”

In the context of this paper, the most important point that came out of the microwave hearing research that I did in

the 1960s is the finding that my human subjects were reporting headaches. I found that I also was getting headaches when I was in the microwave field, and I do not get headaches. I reported the headache phenomena in the 1960s (5).

At that time I could not do experimentation on the headache phenomena. Little was known about headaches and there were no suitable animal models. I was sufficiently concerned about the headache phenomena that I stopped doing microwave hearing research with humans. In sum, 30 years ago I encountered and reported headaches from microwave energy exposure at approximately the same frequencies, modulations, and incident energies that present day cellular telephones emit.

Two other lines of research done at that time bear on the cellular telephone headache question: one involves the blood–brain barrier, and the other involves the dopamine–opiate systems of the brain.

Blood–Brain Barrier

The blood–brain barrier separates the brain and cerebral spinal fluid of the central nervous system from the blood. It primarily consists of an essentially continuous layer of cells lining the blood vessels of the brain. It is a critical regulatory interface.

Recent data indicate that breakdown of the blood–brain barrier may be involved in headaches (11–13). There is significant evidence in the literature that indicates the blood–brain barrier does break down with exposure to low intensity cellular telephone frequency band microwave energy.

Several fluorescent dyes bind to serum protein when injected into the blood stream. These have been used to study the nature of this regulatory interface and have been found to be quite useful. I used one of these, sodium fluorescein, to explore the effects of exposure of animals to microwave energy (14). I found penetration of the barrier in response to exposure to microwave energy; fluorescence was found in the diencephalon level of the brain as well as, to some extent, in the mesencephalon and metencephalon. The differences in brain fluorescence between the exposed and

Table 1. Transmitter parameters of current cellular telephone systems

	Analog	NADC	GSM
Transmitter frequency (MHz)	824–849	824–849	890–915
Average power (mW)	600	200	118
Modulation	FM	50 pps 6.7 msec pulse width	217 pps 0.6 msec pulse width

Abbreviations: NADC, North American Digital Cellular System; GSM, Group Systems mobiles; pps, pulses per second.

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sham-exposed animals was statistically significant. Pulse-modulated energy was more effective than continuous (14).

Oscar and Hawkins (15) extended the work by exposing rats to microwave energy to assess the uptake of several radioactive neutral polar substances in the brain. They observed barrier permeability increases for mannitol and inulin but not for high molecular weight dextrin. The apparent permeability change, which was reversible, was greatest in the medulla, followed in decreasing order by the cerebellum and hypothalamus. It was also found that microwave energy exposure of the same average power but with different pulse characteristics produced different uptake levels.

Albert (16) and Albert and Kerns (17), using yet another technique, exposed Chinese hamsters to microwave energy and injected them with various electron dense tracers. Specimens were then prepared for light and electron microscopic examination. The exposed and sham-exposed groups differed in that exposed animals showed tracer penetration of the barrier in the cerebral and cerebellar cortices, medulla, thalamus, and hypothalamus. Thus, a picture was unfolding which indicates that low intensity microwave exposure opens the blood-brain barrier, a particularly important biological effect.

But then the field was thrown into confusion. Over a 2-year period, J.H. Merritt made oral presentations in which he stated that he replicated the Frey et al. work (14) and Oscar and Hawkins work (15) and could not find an effect. When he finally submitted a manuscript for publication, a statistical analysis of the presented data by the editor and a reviewer showed that, in fact, his data supported the opposite conclusion and provided a confirmation of the findings of Frey et al. (14). When the editor brought this to his attention and asked him to revise the paper to include the data analysis and to revise his conclusions, Merritt withdrew his manuscript (18,19). Over a 2-year period, A.W. Guy et al. also made oral presentations in which they reported that they had replicated earlier work using fluorescent dyes and did not find a change in the blood-brain barrier, but they did not make available details of their methods and the statistical analysis underlying their conclusions. When details were eventually obtained, it was found that they used intraperitoneal injections instead of intravenous injections, as used in the other studies without compensating for the injection method and differences in time for the blood to deliver the dye to the blood-brain barrier. The dye did not have time to fully reach the blood-brain barrier. They also inappropriately used the *t*-test to compare exposed and control groups,

using data with high variability, an ordinal scale, and only four animals in each group (18,20). Thus, the data actually were quite consistent and indicated that the blood-brain barrier opens in response to low intensity microwave energy exposure. At this point, the U.S. Department of Defense decided to effectively terminate funding for blood-brain barrier experiments that used low intensity microwave energy (18,19).

The data that was collected before this line of research was terminated, considered with recent data indicating that blood-brain barrier permeability is involved in headaches, suggest that the reported headaches associated with cellular telephone use are real and may be due to the cellular telephone emissions. [I also found and reported that the blood-vitreous humor barrier of the eye was affected by low intensity microwave energy exposure (21,22). This might also be of consequence in cellular telephone use.]

Dopamine-Opiate Systems of the Brain

There is now data in the literature which indicates that the dopamine-opiate system may be involved in headaches (23-25). This is of consequence because it provides yet another basis for the belief that cellular telephone-associated headache reports have a basis in fact. There is a substantial body of data indicating that the dopamine-opiate systems are influenced by electromagnetic fields, including those at cellular telephone frequencies (26).

In the early 1970s, I hypothesized that the dopamine systems of the brain, in part, mediate the effects of exposure to electromagnetic fields (27,28). A series of experiments to test the hypothesis indicate that the dopamine systems of the brain are involved (26,29). I extended the dopamine hypothesis to include the opiate systems and provided a comprehensive integration of the evidence, indicating an effect of electromagnetic fields on the brain's dopamine-opiate systems (30,31). A series of experiments followed that supported the hypothesis (26).

Thus, there is now a substantial body of data indicating that brain systems, particularly the opiate-dopamine systems, are influenced by exposure to brief, very low intensity electromagnetic fields. These systems could be involved in the reported headaches.

Discussion

The use of hand-held cellular telephones raises a number of questions. Are these telephones safe? There is an abundance of evidence to support a conclusion that the reported headaches from cellular telephone use are a real phenomena. Thirty years ago,

headaches as a consequence of exposure to low intensity microwaves were reported in the literature. These headaches were observed during the course of microwave hearing research before cellular telephones were developed. The blood-brain barrier appears to be involved in headaches, and low intensity microwave energy exposure affects the barrier. The dopamine-opiate systems of the brain appear to be involved in headaches, and low intensity electromagnetic energy exposure affects those systems. In all three lines of research, the energy used was approximately the same in frequencies, modulations, and incident energies as those emitted by present day cellular telephones. These current reports of headaches may be the canary in the coal mine, warning of biologically significant effects.

The use of cellular telephones exposes nearby people, as well as the users, to microwave energy. Should this be allowed? There is not sufficient data at this time to answer this question; but in view of the fact that there has not been a reasonable search for such data, should people be exposed to second-hand microwave emissions without their consent?

There are a few people who would claim that there has been a search, as indicated by studies on the biological effects of microwave emissions which have not revealed a hazard. But the conflicts of interest and questions on the actions of those who decided what research was done and published have been documented by Steneck (18,19). Thus, this claim that there has been a search is hardly credible. Nothing much has changed in the control of this area of biological research, as far as I can see, since Steneck did his in-depth study of this research area. (Steneck, at the time, was Director of the Collegiate Institute for Values and Science at the University of Michigan, Ann Arbor. He and institute fellows in biology and physics did their case study with a major grant from the National Science Foundation's Program for Ethics and Values in Science and Technology.)

REFERENCES

1. Reports of headaches emerge among cellular phone users in U.S. *Microwave News* XVI(6):10 (1996).
2. EMF-Link. Information Ventures Web page, <http://infoventures.com/forms/webfind.html> (1996).
3. Frey AH. Auditory system response to radio frequency energy. *Aerosp Med* 32:1140-1142 (1961).
4. Frey AH. Human auditory system response to modulated electromagnetic energy. *J Appl Physiol* 17:689-692 (1962).
5. Frey AH. Effects of microwaves and radio frequency energy on the central nervous system. In: *Biological Effects and Health Implications of Microwave Radiation* (Cleary, S, ed). PB193898. Washington, DC: Food and Drug Administration, 1969;134-139.

6. Frey AH, Eichert E. Psychophysical analysis of microwave sound perception. *J Bioelectricity* 4:1-14 (1985).
7. Wilson B, Joines W. Mechanisms and physiological significance of microwave action on the auditory system. *J Bioelectricity* 4:495-525 (1985).
8. Frey AH, Corin E. Holographic assessment of a hypothesized microwave hearing mechanism. *Science* 206:232-234 (1979).
9. Frey AH, Messenger R. Human perception of illumination with pulsed UHF electromagnetic energy. *Science* 181:356-358 (1973).
10. Puranen L, Jokela K. Radiation hazard assessment of pulsed microwave radars. *J Micro Power Electromagn Energy* 31(3):165-177 (1996).
11. Sandyk R, Awerbuch GI. The co-occurrence of multiple sclerosis and migraine headache: the serotonin-ergic link. *Int J Neurosci* 76:249-257 (1994).
12. Janigro D, West GA, Nguyen TS, Winn HR. Regulation of blood-brain barrier endothelial cells by nitric oxide. *Circ Res* 75(3):528-538 (1994).
13. Winkler T, Sharma HS, Stalberg E, Olsson Y, Dey PK. Impairment of blood-brain barrier function by serotonin induces desynchronization of spontaneous cerebral cortical activity: experimental observations in the anaesthetized rat. *Neuroscience* 68(4):1097-1104 (1995).
14. Frey AH, Feld S, Frey B. Neural function and behavior: defining the relationship. *Ann NY Acad Sci* 247:433-438 (1975).
15. Oscar KL, Hawkins TD. Microwave alteration of the blood-brain barrier system of rats. *Brain Res* 126:281-293 (1977).
16. Albert EN. Light and electron microscopic observations on the blood-brain barrier after microwave irradiation. In: *Proceedings of Symposium on Biological Effects and Measurement of Radio Frequency/Microwaves*. Rockville, MD: Food and Drug Administration, 1977;294-304.
17. Albert EN, Kerns JM. Reversible microwave effects on the blood-brain barrier. *Brain Res* 230(1-2):153-164 (1981).
18. Steneck NH. *Risk/Benefit Analysis: The Microwave Case*. San Francisco, CA: San Francisco Press, 1982.
19. Steneck NH. *The Microwave Debate*. Cambridge, MA: The MIT Press, 1984.
20. Frey AH. On microwave effects at the blood-brain barrier. *Bioelectromagnetics Society Newsletter*, Nov. 1980;28.
21. Frey AH. Blood-brain, blood-vitreous humor, and placental barrier modification due to microwave exposure [abstract]. *Biophysical J* 21(3):110a (1978).
22. Frey AH. Possible modification of the blood-vitreous humor barrier of the eye with electromagnetic energy. *J Bioelectricity* 3:281-292 (1984).
23. Del Zompo M, Lai M, Loi V, Pisano MR. Dopamine hypersensitivity in migraine: role in apomorphine syncope. *Headache* 35(4):222-224 (1995).
24. Villeneuve A. Pathophysiology and treatment of negative symptoms. *Can J Psychiatry* 39 (9 suppl 2):PS53-58 (1994).
25. Barbanti P, Bronzetti E, Ricci A, Cerbo R, Fabbrini G, Buzzi MG, Amenta F, Lenzi GL. Increased density of dopamine D5 receptor in peripheral blood lymphocytes of migraineurs: a marker for migraine? *Neurosci Lett* 207(2):73-76 (1996).
26. Frey AH, ed. *On the Nature of Electromagnetic Field Interactions with Biological Systems*. Austin, TX: R.G. Landes Co., 1994.
27. Frey AH, Spector J. Irritability and aggression in mammals as affected by exposure to electromagnetic fields. Presented at the URSI Annual Meeting, Amherst, MA, 1976.
28. Frey AH, Spector J. Exposure to rf electromagnetic fields decreases aggressive behavior. *Aggress Behav* 12:285-291 (1986).
29. Frey AH, Wesler L. Modification of tail pinch consummatory behavior in microwave energy exposure. Presented at the URSI Annual Meeting, Seattle, WA, 1979.
30. Frey AH. Biological mediators and mechanisms for low intensity electromagnetic effects. Presented at the Bioelectromagnetics Society Third Annual Meeting, Washington, DC, 1981.
31. Wesler L, Frey AH. Microwave energy interaction with the dopamine and opiate systems of the brain. *Bioelectromagnetics Society Third Annual Meeting*, Washington, DC, 1981.



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