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MR 166

Microwave Lens Effects in Humans

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All personnel presumed to have been exposed on the basis of long-standing occupational circumstances to microwaves at the highest levels encountered in a military operational environment were subjected to biomicroscopic examination of the lens. One hundred thirty-five control personnel were also examined along with them, the examiners having no knowledge of the exposure history of any examinee prior to or during the examination. Objective evidence of lens abnormality (opacities, vacuoles, or posterior subcapsular iridescence) was recorded and a statistical comparison made between the two groups on the basis of this evidence. The comparison showed the groups to be essentially the same and did not support the hypothesis that human cataracts are being caused by chronic exposure to microwaves in the military environment in this country.

MICROWAVES ARE usually defined as that portion of the electromagnetic spectrum generally occupying the region between 1 meter and 1 mm in wavelength. This may also be expressed in terms of frequency, since microwaves travel through space at the speed of light: 3×10^8 cycles per second (300 megahertz) and 3×10^{11} cps (300 gigahertz), respectively. These boundaries are not rigid. Wavelengths several meters long can be considered as microwaves, but this begins to encroach on the short end of very high frequency (VHF) radio waves. Similarly, wavelengths as short as 0.1 mm may be called microwaves, but this then encroaches on the long end of the "far infra-red" region.

Sources of microwaves include instruments known technically as "magnetrons," "klystrons," "travelling wave tubes," "parametric and molecular oscillators," and "harmonic generators." These are more familiar as the radiation sources in radar and other types of communication equipment as well as in microwave ovens and diathermy machines. The majority of this equipment emits microwaves in the 1 cm to 20 cm wavelength range.

In addition to describing microwaves in terms of their wavelength, (or its reciprocal correlate, frequency) one must consider them in terms of the other major variable of wave forms: height or amplitude. This is

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Table 1.—Microwave Workers

Age Group (yr)	Size of Group	Opacities	Vacuoles	PSCI	"Negative" Results
20-29	15	0 (0%)	2 (13%)	3 (20%)	11 (73%)
30-39	21	5 (24%)	7 (33%)	5 (24%)	11 (52%)
40-49	31	10 (32%)	8 (26%)	17 (55%)	9 (29%)
50-59	18	7 (39%)	4 (13%)	13 (72%)	3 (17%)
60-69	6	4 (67%)	3 (50%)	4 (67%)	0 (0%)
Total	91				

related directly to energy level. When discussing microwaves this is expressed in watts, or more frequently milliwatts and microwatts, and is related to surface area, usually in terms of square centimeters. The resulting "power density" of microwaves is therefore expressed as milliwatts or microwatts per square centimeter.

Other factors which complicate the estimation of energy levels affecting biological systems are the concepts of "duty cycle" and "far-field vs near-field." The first factor relates to the intermittency of microwave emanation from most of the foregoing equipment when in use. This results in peaks and troughs, so that the duty cycle is described in terms of its frequency, its peak power, and its average power. These terms are usually applied to the equipment itself, which is described in units of electrical power: kilowatts or megawatts. The "far-field" relates to the fact that beyond certain distances from microwave emanators, the energy level behaves essentially as it does with light and sound, ie, it decreases proportionately to the reciprocal of the square of the distance. But inside that distance, which is different for every source, the area is called the "near-field" and has a much different pattern of energy distribution, with so-called hot-spots of high energy density occurring farther from the source than other relatively "cold-spots" which may be quite close to it.

Power densities of microwaves may be relatively simple to determine theoretically in the far-field but are much more difficult to measure in actual practice. One cause of this difficulty is the fact that most means of measuring microwave power density are indirect methods and subject to inaccuracy. Another cause is that introduction of measuring equipment into a microwave field often changes the characteristics of the field itself, so that "hot spots" and "cold spots" are created. As a result, the validity of field measurements as representative samples of power density from any particular microwave source is often challenged.

The ability of microwaves to cause cataract in the eye of an experimental animal has been well-established by many investigators.[1-3] It is generally supposed that their tissue effects are due to heating,[4] although there is some evidence that there may also be specific nonthermal effects.[5] There is also some experimental evidence for cumulative effects of presumably subthreshold levels.[6]

Claims that individual cases of cataract in humans have been due to microwaves have been difficult or impossible to substantiate for the following reasons: (1) lack of accurate environmental surveillance; (2) lack of information regarding thresholds for microwave damage to human lenses; (3) lack of generally accepted evidence that human microwave cataract has a characteristic morphology; and (4) occurrence of cataracts of varying morphology in the population at large.[7]

Table 2.—Controls

Age Group (yr)	Size of Group	Opacities	Vacuoles	PSCI	"Negative" Results
20-29	37	0 (0%)	4 (11%)	9 (24%)	25 (68%)
30-39	32	6 (19%)	6 (18%)	10 (31%)	15 (47%)
40-49	38	10 (26%)	10 (26%)	21 (55%)	9 (24%)
50-59	20	6 (30%)	7 (35%)	17 (85%)	6 (30%)
60-69	8	1 (13%)	2 (25%)	4 (50%)	3 (38%)
Total	135				

Some instances of human cataract being ascribed to microwave have appeared in the ophthalmology and preventive medicine literature.[8,9] In all of these cases, cataracts appeared in the eyes of individuals in the age group in which cataracts are expected to appear: no unusual exposure to microwave energy was documented in any of them, and no clinical characteristic of their lens opacities to distinguish these from other types of lens opacity was documented in any of them. In all cases, the microwave etiology of the cataracts was only presumptive, and in no case were data presented to substantiate it. By contrast, in the two instances of presumed overexposure to operational microwaves which we have observed during the past 18 months, both equipment operators were men in the third decade, and no biomicroscopic evidence of lens abnormality has appeared.

Few studies have been published which deal with whole populations exposed to microwave energy.[10] In the present study, a population associated with microwaves to varying degrees was subjected to ophthalmological examination and compared to a population not associated so great an extent with them. Rather than requiring the examiners to determine the presence, absence, or extent of "cataract," the study was designated to detect and record only those biomicroscopic signs which the ophthalmologist takes into account when making the clinical diagnosis of cataract.

Materials and Methods

Two hundred twenty-six personnel were examined semi-annually between November 1968 and May 1971. Since all personnel were not available for all examination sessions, some were examined as many as six times, while some were examined only once. These personnel were all employees of the Department of the Army at Ft. Monmouth, NJ, a post at which a vast amount of Signal Corps electronic communication, detection, guidance, and weather equipment has been tested, developed, and used. Included in this array of equipment have been many instruments using microwave sources, some of them rather powerful emitters, and the potential for personnel exposure to this type of radiation has probably been at the highest level encountered in this country. Some of the workers examined have been involved in this type of work since 1943.

Selection of personnel examined was based upon the post's Occupational Vision Program. All personnel who had histories of working with equipment using microwaves, laser, xenon arcs, ultraviolet, and welding equipment (to include plasma torches) were requested to participate in the survey.

The examination performed included visual acuity determination, followed by dilation of the pupil with a short-acting mydriatic/cycloplegic agent. The fundus was then examined by direct ophthalmoscopy with special attention paid to the details of the posterior pole. The anterior segment was then examined with a slit lamp having a beam-splitter and observation tube attached. Note was made of the following:

1. Presence or absence of opacities visible as shadows against the red reflex seen in the coaxial (lighting and viewing lines coincident) view. If present, their number, location, and shape was also recorded.

2. Presence or absence of vacuoles. If present, their number and location was also recorded.

3. Presence or absence of posterior subcapsular iridescence (PSCI), a polychromatic luster caused by interference patterns at the level of the posterior lens shagreen when the angle of illumination and of viewing are equal with respect to the normal line for the region where the sutures meet and in the same horizontal plane as this line.

4. Absence of all of the foregoing signs was referred to as "negative" results of the examination.

Any opacities or vacuoles which were sufficiently extensive were photographed using a hand-held fundus camera focused for anterior segment work, giving a photographic view similar to that seen in the coaxial view of the slitlamp.

The population was then divided on the basis of microwave history. Those individuals who gave a history of working directly with microwaves, either as test-development personnel or as operators of the equipment, were considered "experimental." Those individuals who worked at Ft. Monmouth but who denied ever having worked with or near this equipment were considered "controls." The examiners were not aware of the microwave exposure history of these subjects before examining them.

The results are presented in Tables 1 and 2.

Comment

Because the format and criteria for a standardized ocular examination of micro-

wave workers was established only recently, the results of any prospective clinical studies will not be available until several years hence. Meanwhile, such retrospective studies as this one can provide interesting information. It appears from this study that available clinical evidence does not support the assumption that cataracts which develop in personnel performing duties in the vicinity of microwave generating equipment are a result of microwave exposure, unless a specific instance of severe exposure can be documented and correlated with subsequent cataract development.

Key Words.—Military; microwaves; radar; klystrons; lens; cataract opacities; vacuoles; iridescence.

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CORRECTIONS

Line Omitted.—In the July issue of the ARCHIVES, a sentence was omitted in the article by Fox titled "Upper Lid Reconstruction" (88:46-48, 1972). On page 46, column 1, the last line (given here in italics) should read "Attached grafts were not wholly *abandoned. On the contrary they were . . .*"

Table Footnote.—In the July issue of the ARCHIVES, an error occurred in Pollikoff et al's article, "Herpes Simplex Virus Infection in Rabbit Eye" (88:52-57, 1972). On page 53, the last paragraph of the footnote to Table 2 should read: "All rabbits were pretreated for 24 hours with a given preparation."