MR 820

AUTHORS: Hirsch FG, Parker JT:

DATE: 1952

TITLE: Bilateral lenticular opacities occurring in a technician operating a microwave generator.

SOURCE: AMA Archives of Industrial Hygiene and Occupational Medicine 6: 512-517

MAIN SUBJECT HEADING:

AN	HU	AT	IH	M
ANALYTICS	HUMAN EFFECTS	ANIMAL TOXICITY	WORKPLACE PRACTICES-ENGINEERING CONTROLS	MISCELLANEOUS

SECONDARY SUBJECT HEADINGS: AN HU AT IH M

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Reprinted from the A. M. A. Archives of Industrial Hygiene and Occupational Medicine
December 1952, Vol. 6, pp. 512-517

BILATERAL LENTICULAR OPACITIES OCCURRING IN A TECHNICIAN OPERATING A MICROWAVE GENERATOR

FREDERIC G. HIRSCH, M.D.
AND
JOHN T. PARKER, M.D.
ALBUQUERQUE, N. MEX.

EXPERIMENTS have been undertaken in a number of laboratories to determine the response of various tissues and organ systems to high-power microwave radiation.[1] These studies have established the fact that living cell systems respond qualitatively to microwave radiation by the conversion of the energy to heat in a manner similar to their response when exposed to conventional short-wave diathermy. Although some investigators have felt that the quantitative differences which are observed are due to a decreased penetrability of the shorter wave length of the microwave,[2] the matter should not be so simply dismissed. Provided there are no differences in dielectric constant, in discontinuity, or in the loss coefficient of this discontinuity, shorter wave lengths will penetrate much less into any particular physical environment than will longer ones. It is known that a given amount of wave-form energy will become more concentrated in space as the frequency is increased. Thus it would appear that the quantitative difference in effect between conventional short-wave diathermy and microwave emanations is due to these energy packets, to loss coefficient decreases, and to more profound changes in the dielectric constant of tissue, as well as to their shorter wave lengths. All these

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From the Departments of Occupational Medicine (Dr. Hirsch) and Ophthalmology (Dr. Parker), Lovelace Clinic, Albuquerque, N. Mex.

1. (a) Richardson, A. W.; Duane, T. D., and Hines, H. M.: Experimental Lenticular Opacities Produced by Microwave Irradiations, Arch. Phys. Med. **29**:765 (Dec.) 1948. (b) Moncreiff, W. F.; Coulter, J. S., and Holmquest, H. J.: Experimental Studies in Diathermy Applied to the Eye and Orbit; Comparison of the Thermal Effects of Diathermy, Infrared Radiation and Electric Heating Pad, Am. J. Ophth. **16**:193 (March) 1933. (c) Osborne, S. L., and Frederick, J. N.: Microwave Radiations: Heating of Human and Animal Tissues by Means of High Frequency Current with Wavelength of 12 Centimeters (Microtherm), Council on Physical Medicine, J. A. M. A. **137**:1036 (July) 1948. (d) Daily, L. Jr.; Wakim, K. G.; Herrick, J. F., and Parkhill, E. M.: Effects of Microwave Diathermy on the Eye, abstracted, Am. J. Physiol. **155**:432 (Dec. 1948. (e) Cogan, D. G.: Lesions of the Eye from Radiant Energy, J. A. M. A. **142**:145 (Jan.) 1950. (f) Salisbury, W. W.; Clark, J. W., and Hines, H. M.: Exposure to Microwaves, Electronics **22**:66 (May) 1949. (g) Clark, J. W.: Effects of Intense Microwave Radiation on Living Organisms, Proc. Inst. Radio Engrs. 1028-1032, Sept., 1950.

2. Murphy, A. J.; Paul, W. D., and Hines, H. M.: A Comparative Study of the Temperature Changes Produced by Various Thermogenic Agents, Arch. Phys. Med. **31**:151 (March) 1950.

parameters are presumed to be functions of frequency, although little is known about some of them in biological systems.

It has been learned that those tissues which have poor blood supplies, those which contain more or less static concentrations of fluid, and those whose component proteins are easily coagulated by heat can be damaged to a serious degree by irradiation with appropriate parameters of microwave energy. These parameters are wave length, time, and intensity of output. The latter factor is a rather complicated one to evaluate, since to do so necessitates a consideration of directivity (Poynting vector) and of focusing effects, as well as the more readily appreciated factor of power output.

It would appear that wave lengths of between 8.0 cm. and 15.0 cm. at power levels of above 10 watts per square decimeter (CW, or average) are readily capable of causing extensive, irreversible tissue damage. As in other situations, the power level must be multiplied by the duration of exposure in order to arrive at dosage considerations. Of all the organ systems studied, apparently the eye and the testicle are the organs most vulnerable to microwave irradiation.[1g]

In spite of the fact that damage can be demonstrated to be the result of the deliberate irradiation of tissue, providing the proper wave lengths and intensities are employed for an adequate length of time, it has been the feeling of most people that personnel working with microwave generators are not subjected to any great hazard.[3] This feeling is derived from the experience of many in places where microwave operations are commonplace, and where the exposure of a great many persons must have been extensive. In addition, a therapeutic microwave generator has been on the market for a number of years. This apparatus has been studied and approved by the Council on Physical Medicine and Rehabilitation of the American Medical Association for use in place of conventional diathermy. One may assume that a large number of these generators are in daily use, and yet no reports of any adverse effects have been published in the medical literature.

It is very difficult to get precise measurements of the intensity of exposure occurring in personnel who operate microwave equipment. It is only by using precise apparatus, in which the energy is confined to transmission lines, that one can approach an accurate measurement of power. An operator works in what is known as a "near field" situation. The ability to make measurements in this environment is poor. A number of things enter into the consideration concerning which there is little information. By these things are meant the coefficient of reflection from the various body surfaces, such as the anterior surface of the eye, the higher frequency modes which may set up in tissue, and the effects of focusing. For these reasons it has not been possible to formulate any parameters of safe exposure levels. Not much need for them has been felt, as a matter of fact, since the feeling has grown up that only deliberate and intense effort to cause damage would suffice to bring it about. It has not been anticipated that hazards to operating personnel would be anything more than remote possibilities. The case in point may serve as a reason for reevaluation of the matter.

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3. Daily, L. E.: A Clinical Study of the Results of Exposure of Laboratory Personnel to Radar and High Frequency Radio, U. S. Nav. M. Bull. **41**:1052 (July) 1943.

REPORT OF A CASE

The case reported in this communication is of distinct interest, since it raises questions and poses a problem in the evaluation of circumstantial evidence.

The patient, a 32-year-old white man, prior to his present employment ran a radio-service shop, where his contact was mainly with standard broadcast receivers, record players, and electronic equipment of that sort. He had been (and still is) an enthusiastic amateur broadcast operator for a number of years but had not been directly concerned with frequencies in the microwave range. He was not associated with any microwave activities during the recent war. In the fall of 1950 he set up a microwave test bench and used it from November, 1950, to October, 1951. His equipment included an experimental microwave generator tunable from about 9 to 18 cm. wave length and having an average power output of 100 watts on a 50% duty cycle. His test line was terminated by a horn antenna which dissipated the power into a room. Most of his work was done in the region of the longer wave lengths available to him. It has been calculated that the intensity of radiation at a plane coinciding with the rim of the dissipating antenna was about 0.1 watt per square centimeter.

Fig. 1.—Diagram of the relative positions occupied by the output array and the operator at the time of maximum exposure intensities.

A habitual practice of this operator is worthy of mention, since it may well have some bearing on the case. In order to determine whether or not the equipment was generating energy, he made a regular practice of placing his hand in the dissipating antenna of the oscillator and noting the heating effect on his hand. In these circumstances it was necessary for him to look into the antenna in order to place his hand properly. As will be subsequently emphasized, he was somewhat myopic, and so his face was practically in a plane coincident with the rim of the antenna when performing this maneuver.

On Oct. 11, 1951, he presented himself to one of us (FGH) with the chief complaint of an inability to see clearly. It was, he stated, as though he were in a tank of water with his eyes open, so that everything he looked at seemed "blurred and wavy." This visual disturbance had developed, he said, over a period of about a week or 10 days. He was not aware of any loss of visual acuity prior to that time. It is also worth noting that one week before he first complained of blurry vision he was engaged for a period of three days during which he worked intermittently, from six to eight hours at a stretch, with the output array quite close (10 to 50 cm.) to his head (Fig. 1). He said that on these days, upon returning home, his wife remarked that his eyes were "bloodshot."

It has been estimated that the average daily exposure of this operator was of the nature of 0.5 W./dm.²/day ± 15%. On the days when the more intense exposure to his head occurred the exposure is estimated at about 12 W./dm.² for a total of two hours. These figures are not exact, owing, as has been pointed out, to the difficulty of making exposure measurements.

The initial examination revealed a normal white man in apparent good health. A general physical examination revealed no abnormalities except for the eyes. His visual acuity was

Fig. 2.—The external appearance of the eyes before treatment.

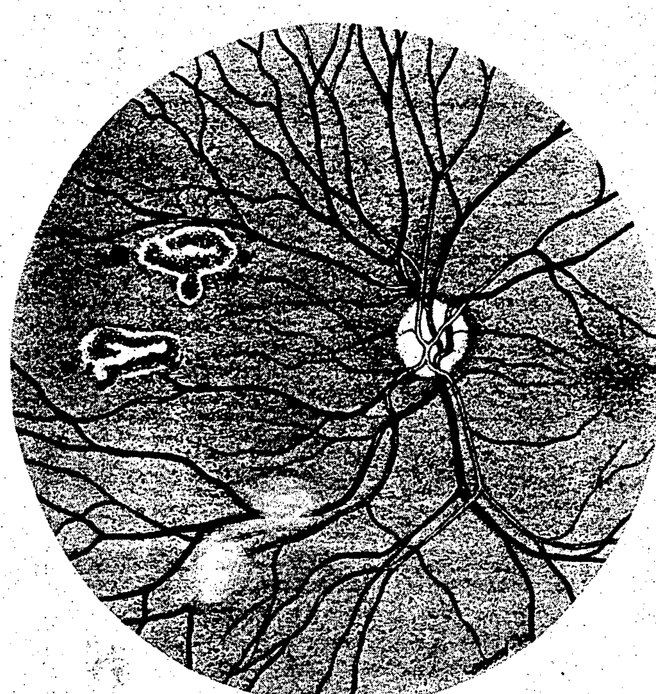

Fig. 3.—The appearance of the left fundus before treatment.

measured at OD 20/60; OS 20/200. This was a marked change from the acuity recorded at the time of a routine examination for employment done about a year earlier. The latter examination showed that on Nov. 27, 1950, he had an acuity of 20/40 in the right eye and 20/40 in the left eye for distance and Jaeger 1 in both eyes for near vision.

The patient was given a thorough ophthalmologic examination (JTP), which revealed the following findings:

The unaided visual acuity was 20/60 in the right eye and 20/200 in the left eye. There was slight bulbar injection in both eyes. Slit-lamp examination showed both corneas to be normal except for a few small nonpigmented precipitates on the left cornea. Both lenses showed slight roughening of the anterior capsules and moderate nuclear opacities. The left posterior lens capsule showed, in addition, several small scattered areas of irregular thickening. Ophthalmoscopy of the right fundus revealed it to have a normal appearance throughout, except for a few tiny vitreous opacities. In the left fundus, however, there were two irregular choroidal lesions, about one-fourth to one-half disk diameter in size, located about four disk diameters from the optic nervehead in the horizontal meridian. These were surrounded by dense pigmentation. Below them and about the same distance from the nervehead were two poorly defined white edematous areas. The vitreous humor of the left eye contained many large and small opacities. A diagnosis of bilateral nuclear cataracts with acute left chorioretinitis was made as a result of these findings. Figure 2 shows the external appearance of the eyes, and Figure 3 is an artist's rendition of the appearance of the left fundus to ophthalmoscopy.

Because of the acute inflammatory appearance of the lesions in the left retina, the patient was hospitalized and treated for a period of 10 days. During this time 40 mg. of corticotropin was administered daily. In addition, 0.2 cc. of cortisone was injected subconjunctivally into the left eye. During this period of therapy the inflammatory signs disappeared. It was felt, however, that the lenticular opacities gradually increased in size and density. At the conclusion of the hospital treatment a manifest refraction revealed vision in the right eye of 21/100 with a —4.75 sph. ⊃ —1.75 cyl., and in the left eye of 20/200 with a —4.50 D. sph.

The patient was subsequently examined by Dr. Ralph W. Danielson, of Denver on Jan. 2, 1952. His findings are as follows:

"*Right Eye.*—Externally the eye appears normal. The pupillary reactions are normal. The intraocular tension to fingers is entirely normal. The muscle balance is normal. The uncorrected vision is a poor 20/200. With a very uncertain correction of —2.00 sph. ⊃ +3.00 cyl., axis 90, the patient reads a poor 20/100 for distance, and 14/35 for near. The pupil dilates freely with a cycloplegic. With the slit lamp one can see a few cells, but no flare in the anterior chamber. The lens shows a moderate nuclear opacity. The posterior capsule shows scattered, incipient, multiple opacities in the subcapsular area, but these are not at all striking. Between the posterior capsule and the nucleus there is slight opacification of the cortex. Here and there one can see a few definite specks of increased opacity. The vitreous appears normal. With the ophthalmoscope the retina appears entirely normal in all areas, although the examination is somewhat impeded by the nuclear opacification. Under cycloplegia one can get fairly satisfactory skiascopy findings, much better than one would have expected considering the diminution of visual acuity present. The retinoscopic finding is —5.00 sph. ⊃ +1.00 cyl., axis 80. The uncorrected vision is less than 20/200, but with a —4.00 sph. ⊃ +3.00 cyl., ax. 70, the corrected vision is 20/200. Thus his acuity is slightly better when the pupil is dilated. The peripheral field and blind spot are normal using a 5/330 text object.

"*Left Eye.*—The left eye is quiet, showing no evidence externally of acute inflammation. The intraocular tension and muscle balance are normal. The pupil reacts normally. The uncorrected vision is a poor 20/200. With a —2.00 sph. ⊃ +3.00 cyl., axis 100, the corrected vision is 20/200 for distance and 14/42 for near. The pupil dilates freely with cycloplegia. On looking with the slit lamp one can see no flare, but a considerable number of cells are present in the anterior chamber. The lens picture is essentially the same as that seen in the right eye except that it is less marked. With the slit lamp, however, one can see numerous cells in the retrolental space and in the anterior vitreous humor. With the ophthalmoscope, one can see many large and small opacities throughout the vitreous humor. In the fundus, nasal to the disk, one can see three definite lesions. Two of these lesions are rather large, are white in the center, and are surrounded by a thick, black pigment ring. Below these two older lesions, and on a line with them, one can see a smaller white area without any surrounding zone of pigment. This seems to be an area of active choroiditis. Under cycloplegia, no adequate skiascopy can be performed, partly because of the lenticular opacity and partly because of the vitreous debris. However, with a —4.00 sph. ⊃ +1.00 cyl., axis 130 the visual acuity is brought up to 20/100. The peripheral field and the blind spot are normal using a 5/330 test object.

"*Opinion.*—The lenticular opacities in this case seem to be essentially the nuclear rather than the subcapsular type which has been reported in the literature as being the result of ionizing radiation. However, obviously no one has had enough experience with the situation to say definitely whether or not these cataracts are secondary to exposure to microwave radiation. The cause of the choroiditis in the left eye is at present unknown, but further observation of this patient may throw additional light on that aspect of the matter. Ordinarily, one would not think of microwave radiations as a cause of choroiditis, but one certainly cannot rule out such an etiology, if only as an aggravating agent."

With the passage of time, the choroidal lesions have become inactive. No attempts have been made thus far to remove the lenses. It has been felt wise to await as complete a clearance of the inflammatory changes as possible before surgery is undertaken. It may or may not be necessary to administer another course of corticotropin, cortisone, or perhaps typhoid vaccine in order to reach an optimum condition for surgery.

COMMENT

It is very difficult in a case such as this to resist the temptation offered by circumstantial evidence and thus unequivocally to ascribe the ocular pathology to irradiation by microwave energy. However, to do so would vitiate the value of the lessons which such a case is capable of teaching. True it is that under the experimental conditions set up by previous workers it is possible to produce coagulation of lenticular protein with the result that the lens becomes opaque. True it is also that many thousands of man-hours have been spent in the operation of various types of microwave generators without any published reports of the occurrence of lenticular opacities. It must also be remembered that microwave energy has been used as a modality of physical therapy for a number of years without any record of any ocular damage resulting from such use.

It will be well therefore to use this case as a means of recalling the attention of ophthalmologists, industrial physicians, and microwave operators to the potentialities of microwave radiations in order that the use of this form of energy will be accompanied by appropriate respect and precautions. It is also important to realize that much remains to be learned about the various factors which control the absorption of microwave energy by tissue systems in a "near field" situation, to the end that further research may be stimulated.

Until more data have been accumulated, it is probably wise for personnel in daily contact with the energy dissipation arrays of microwave generators, especially when situated in relatively confined spaces, to wear metallic spectacle frames in which a fine copper mesh has been substituted for the ordinary glass lens. Such devices have been shown to afford considerable protection.[1a]

Printed and Published in the United States of America