(NAVY), Glaser
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The probability of developing hypoplastic anemia from occupational exposure to chemicals is much less than from exposure to chemicals used therapeutically. The chief reason for this is inherent in the relative risk. In industry, the level of chemical exposure is normally kept below a level that would produce any effect in any worker. On the other hand, the level of chemical exposure during therapy is deliberately high enough to produce a desired response even though risk of undesirable side effects is appreciable. (Fleming, A.J., The Etiology of Aplastic Anemia - Industrial Chemicals Versus Therapeutic Chemicals: J. Occup. M., 1: 97-99, February 1959)

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by Barron

Medical Considerations of Exposure to Microwaves (Radar)

Considerable interest in the biologic aspects of exposure to radar beams has been generated during the past year by widespread publicity of an alleged case of human death occurring after brief exposure to an unknown quantum of microwaves. The incident served to direct attention to this relatively new agent, and questions naturally arose concerning the extent of the hazard, if any, to persons working with radar transmitters and to those who might be exposed in some manner to the energized beam.

It is not generally known that apprehension over the biologic potentials of microwaves dates back to the early days of World War II, when Daily (1943) performed his original studies on U.S. Navy personnel engaged in the operation and testing of relatively low-powered radars. Although this study revealed no evidence of radar-induced pathology in human beings, numerous reports have since appeared indicating that tissue injury and animal death can occur under certain experimental conditions. These studies indicate that cataracts, corneal opacities, testicular degeneration, and hemorrhagic phenomena have been induced in anesthetized, small, furry, test animals by exposure to microwaves in the frequency range of 2800 to 9000 megacycles for various time exposures. Boysen, using a transmitter with a frequency of 300 megacylces, exposed rabbits in a wave guide and produced damage to the central nervous system, degenerative changes in the kidneys, heart, liver, and gastrointestinal tract, and hemorrhagic changes in the respiratory tree. The power density measured in the wave guide was in excess of 0.1 watts per square centimeter. The animals were exposed for periods of 7 to 10 minutes, and all whose rectal temperatures exceeded 44.5°C. (112.1° F.) died. Boysen was of the opinion that pathology and death were causally related to the hyperthermia. (1953)

Because of these findings and the apprehension engendered by their publication in scientific journals, the medical department of an airframe

manufacturer coincidentally installing, testing, and servicing the most powerful airborne transmitters, early in 1954, instituted a comprehensive medical surveillance program for its several hundred employees working with radar or those who might be exposed to the energized beam. This program constitutes one of the longest continuous medical surveys of radar-exposed personnel in the United States.

The objectives of the program were threefold: (1) to detect any cumulative biologic effects of long-time exposure to microwaves of varying frequency and power output in persons who had taken minimal precautions; (2) to observe possible effects on persons working for short periods with or near extremely highpowered airborne radar with pulsed wave emissions; and (3) to establish correlation between objective findings and units of exposure expressed in time-powered density factors with the highly idealized objective of establishing safe maximum exposure standards.

Effects of Long Periods of Exposure

The initial study included 226 radar-exposed employees and 88 non-exposed control subjects. Examination in every case included an extensive system and organ inventory with emphasis on the ocular structures, central nervous system, gastrointestinal and urinary tracts, hematopoietic system, and skin. Imbedded metallic foreign bodies were identified; a careful marital and fertility history was elicited; and duration and manner of exposure to radar was identified.

In addition, each subject was inspected for manifest hemorrhagic phenomena. A modified test for Rumpel-Leede phenomenon was then performed by means of placing the blood pressure cuff on the arm and maintaining pressure midway between the systolic and diastolic pressure for three minutes. The appearance of more than 10 fresh petechiae in a circle 4 cm. in diameter below the cuff was considered a positive result.

The second phase consisted of an ocular examination, including a slit lamp study performed with the patient subjected to cycloplegia by a competent ophthalmologist, complete blood cell and platelet counts, chest x-rays, and urinalyses.

No pathology or adverse physiologic effects unequivocally attributable to microwave exposure could be demonstrated, and no person sustained any acute or chronic injury secondary to radar exposure.

Effects of Short Periods of Exposure

Having established baseline or reference criteria, personnel were reexamined, at 6-month, then 12-month, and 24-month intervals approximately 4 years after the original study. The procedures were modified to eliminate several more costly, time-consuming, and noncontributory tests. An extensive medical questionnaire was prepared, and each subject was interviewed by a physician. Physical examinations were performed only when

indicated on the basis of the medical history or laboratory studies. Ocular and slit lamp studies were repeated, and complete blood cell counts and urinalyses were performed. Blood platelet studies were repeated on alternate years. A limited number of electrophoretic serum protein patterns were made.

The number of days of sick leave and leaves of absence and other health statistics were obtained. Also, a large number of tests for Rumpel-Leede phenomenon were performed on applicants for employment and employees seeking treatment for routine ailments. None of these subjects had had any known exposure to radar emanations.

The total exposure group increased to 335 by the addition of newly hired or reclassified employees. Persons in the one-year study generally had two examinations, in the 2-year study two or three examinations, and in the 4-year study three or four examinations.

Among the radar-exposed group, sinus, gastrointestinal, genitourinary, and dermatological complaints were most prevalent. Headaches and nervousness were the most common subjective complaints. The control group exhibited sinus, allergic, gastrointestinal, joint, and genitourinary disease prevalence, with fewer headaches and skin and respiratory complaints. There were no marked deviations or trends from the common disorders and no unusual or unexplained hemorrhagic phenomena.

No ocular finding was attributable to radar exposure. There were no cataracts characteristic of those experimentally induced in animals by hyperthermia, and the corneal scars were mainly associated with the other known causative agents. There were no tendencies toward progressive ocular diseases, and the 4-year group revealed no pathology significantly different from that of the other groups.

Sick leave for the 49 subjects who were in the 4-year group averaged 3.0 days for the year 1957 compared to 3.1 days for all factory personnel.

The blood picture of the radar-exposed and control groups was comparable in most respects. An unusually high incidence of increased monocytes and eosinophils was noted. Of the 49 subjects studied over 4 years, only one had a reduced blood platelet count. Of the 88 subjects used in the original control group, positive results were noted in 8%.

In 26 cases selected at random, electrophoresis of serum proteins was performed at a hospital laboratory. Many of these specimens were from subjects in the 2-year and 4-year groups. In only one subject was the deviation more than slight or considered significant, and this was partially reversed within 2 months after elimination of an active known infection.

Maximum Exposure Standards

The delineation of safe maximum exposure standards was contingent upon detection of pathologic changes in the subjects and determination of the exposure parameters with respect to frequency or wave length, field power

density, exposure time, and total test environment. It soon became apparent that this objective could not be achieved in the study because no pathology caused by either single or repeated exposure was uncovered. The majority of personnel had been exposed to radars from transmitters operating in a frequency range of 400 to 9000 megacylces including powerful "S" band components. It was impossible to obtain precise data covering exposure time and average field power density because often these were unknown. Exposure varied from an occasional incidental contact with the beam to as much as 4 hours daily close exposure periods up to 4 years. Exposures of several minutes a day at distances of less than 10 feet from the radars were not uncommon.

Protective clothing was not worn by any of the subjects while in the radar beam. Personnel were advised to avoid exposure to any firing beam when in a zone defined by a minimum power density of 0.0131 watts per square centimeter. A second zone, extending from the area previously defined to that with a minimum power density of 0.0039 watts per square centimeter, was deemed acceptable for occasional pass-through but no constant exposure. The third was a limitless zone in which exposure was not deemed biologically significant.

Unfortunately, because most persons are exposed to radar emanations while on the ground and frequently within the so-called near radar field, it is extremely difficult to evaluate biologic effects and hazards in relation to absolute power levels without accurate measurements. The need for such accuracy in quantitative determinations of exposure is obvious and can be achieved by the development of exposure meters reflecting absorption in quantum units of radar energy.

It has been suggested that the sensation of heat is almost universal on exposure to radar and that this in itself is indicative of an overexposure. In this study, only 17% of the 335 subjects experienced heat sensation and frequently only when in close proximity to "X" band radars. Almost 6% were aware of a buzzing or pulsating sensation when in an"S" band field. Less than 1% experienced other sensations or warning phenomena, such as sparking between dental fillings or a peculiar metallic taste. Eight subjects gave a history of metallic implants, such as bullets, buckshot, steel pins, and plates. None experienced any unusual reaction attributable to the metal. There were no complaints of heat directed to rings, wrist watches, or bracelets.

Comment

During the past 18 years, thousands of persons in the course of their employment or while in military service have been exposed to microwaves, many without protection. Concern over the effects of such exposure is natural and to be expected. The majority of radars in common use today are relatively low powered with the exception of some military transmitters which

exceed one megawatt in peak power output. Radars with many times this power will be operational in due course and may radically change the entire concept of the biologic potentials of this form of energy.

Experiments have been conducted primarily on small fur-bearing animals and under unusual test conditions. It is generally accepted that the modus of injury by microwaves is a hyperthermia produced by absorption of this form of energy by the body. Extreme caution must be exercised in attempting to extrapolate the results of small animal responses to heat to those of the human body. Small fur-bearing animals have a high coefficient of heat absorption, a small body surface, and a relatively poor heat regulating system. The human body, by comparison, has an excellent heat regulating system and can readily adjust and maintain thermal homeostasis under severe stress conditions. Adequate physiologic function can be maintained in environments of 240° F. for 23 minutes if the humidity is low; at least one subject has been exposed to a temperature of 400° F. for approximately one minute without tissue injury.

Conditions of radar operation and testing vary from experimental conditions. Human beings are generally exposed while in free air and rarely to a stationary energized beam. Some radar beams are extremely narrow, and only a small portion of the human body is instantaneously exposed. The body can dissipate heat readily to the environment between such exposures. One is reminded of a similar problem associated with exposure of personnel to the thermal effects of ultrasonic energy. In an analogous situation, small fur-bearing animals were destroyed by hyperthermia when placed in a jet engine noise field, yet there is no evidence of any adverse heating effects on man when exposed to the same environment. It has been estimated that it would require many million times the ultrasonic energy of that generated by any current jet engine to produce these effects in human beings.

A case is recorded of accidental 15-second exposure at a 6 to 10-inch distance to an "X" band radar of over 100,000 watts in peak power output, with resultant erythema and a sensation of warmth for an hour, but with full and uneventful recovery. Unless carefully controlled and operated, microwave diathermy with use of "S" band frequencies can cause local tissue damage.

The study revealed no acute, transient, or cumulative physiologic or pathologic changes in subjects working with, and frequently exposed to, high-power radar transmitters. Therefore, it would appear extremely unlikely that there exists a biologic hazard to the radar technician observing reasonable precautions or that the general public, exposed to greatly attenuated and intermittent doses of microwaves in the environment, is in any danger of body injury.

There is need for additional research to explore the effects on living tissue of extended wave lengths and frequencies of microwaves and transmitters of higher energy.

With the increasing exposure to microwaves in and around the home as well as in industry, careless and scientifically uncorroborated report of human injury and death cannot avoid receiving dramatic and widespread dissemination. If radar is incriminated, the report must contain a definite history of exposure, including proper identification of the transmitter, wave length, power density, exposure time, symptomatology, laboratory data, pathologic findings, and other factors. (Barron, C.I., Baraff, A.A., Medical Considerations of Exposure to Microwaves (Radar): J.A.M.A., 168: 1194-1199, November 1, 1958)

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