OCCUPATIONAL MEDICINE

Hazards of Microwave Radiations - A Review

Since World War II, radar and other microwave equipment have come into use by the Armed Forces, commercial aviation, navigation, and to a lesser extent, by medical science. While it is generally believed that microwaves in these applications are harmless, sporadic reports of injuries attributed to microwaves are in the literature.

The term microwaves is used to designate a certain portion of the electromagnetic spectrum; it generally includes frequencies between 1000 and 30,000 megacylces per second, or in terms of wave length, between 30 cm and one cm.

Two radar bands are now in common use: the "S" band, with a frequency of 2880 megacycles and a wave length of 10.4 cm, and the "X" band, with a frequency of 9375 megacycles and a wave length of 3.2 cm.

Microwaves are used in clinical medicine as a means for heating tissues beneath the skin and subcutaneous fatty layers. The diathermy application depends on the fact that heat is produced wherever microwave or any other energy is absorbed.

Microwave diathermy machines typically have a frequency of 2450 megacycles, a wave length of 12.2 cm, and a power output of 125 watts.

Absorption of Microwave Energy in Tissue. Any biologic effect, beneficial or harmful, produced by microwaves can result only from absorption of energy by the tissues. The amount of energy absorbed by a small volume of tissue in a large mass of tissue subjected to microwave radiation depends on a number of factors:

1. Intensity or field strength of the microwave radiation incident on the surface of the tissue mass
2. Duration of the exposure
3. Frequency or wave length of the microwave radiation
4. Thickness of tissue between the irradiated surface and the small volume of tissue
5. Composition of the tissue

The degree of temperature rise produced in the small volume of tissue will depend on the five factors above and on the ability of the irradiated portion of tissue to rid itself of excess heat. It should be noted particularly that the energy deposition in tissue is dependent on microwave frequency and on composition of the tissue.

Biologic Effects of Microwaves. On purely physical grounds, it can be said that absorption of energy from microwaves or from any other penetrating radiation will raise the temperature of the absorbing material. If the absorbing material is the tissue of a living mammalian organism, the temperature elevation will set in motion a complex sequence of homeostatic mechanisms that tend to restore the normal temperature. Under steady state irradiation conditions, an equilibrium will be attained at a temperature somewhat higher than normal. The human body is capable of dissipating heat at a rate on the order of 0.01 to 0.1 watts per square centimeter of body surface. Thus, the average human body is able to absorb between 100 and 1000 watts of energy from an outside source like microwaves while still maintaining an equilibrium, but an elevated temperature. Higher rates of energy absorption will overpower the regulatory capabilities of the body and lead to a continuous temperature rise and, ultimately, death.

All tissues of the body are not equally equipped for heat dissipation and temperature regulation. The lens of the eye and hollow viscera, such as gallbladder, urinary bladder, and parts of the gastrointestinal tract, for example, are comparatively avascular and largely devoid of effective temperature regulating mechanisms. It is reasonable to expect that such organs will suffer relatively larger temperature rises and will be more liable to injury by microwave irradiation than other body organs. Experiments have, in fact, shown that severe and injurious temperature increases occur in these organs under microwave irradiations accompanied by only slight increases in rectal and oral temperature.

It is not clear whether all biologic effects of microwaves can be attributed solely to temperature increases that result from energy absorption, or whether these effects are produced in part by mechanisms other than simple thermal elevation. Hines and Randall were unable to find any crucial experimental evidence for biologic effects unrelated to temperature change. It should be pointed out, however, that at this time it is impossible to rule out completely the possibility of athermal effects of microwaves.

Experimental Evidence in Laboratory Animals. Hines and Randall in 1952, reported the pronounced effects of high intensity 10 cm microwaves on laboratory animals. Rabbits exposed to a constant 3000 watt field for 75 seconds were killed instantly, and a 30 second exposure produced death within 2 minutes after irradiation was terminated. At this same power level, a rat was killed by a 22 second exposure. A hamster exposed to a 400 watt field died immediately after a 10 second exposure. These lethal effects are attributed to a generalized increase in body temperature which ultimately leads to a thermal paralysis of the respiratory center. Irreversible cellular injury and death may occur when tissue temperature is maintained 5 C above the normal body temperature. Irreversibility of the injury depends on duration of the hyperthermic episode; the higher the temperature the shorter the time necessary to cause cell death.

It was observed that when only a limited area of the body, such as the abdomen, was irradiated, the temperature of the visceral organs was markedly elevated despite normal oral and rectal temperature. Studies with relatively low power levels showed that the rise in brain temperature is not the primary cause of death when the abdomen alone is irradiated, but the elevation of brain temperature is probably the primary cause of death when only the head is irradiated. Oldendorf, employing 12.5 cm microwaves, demonstrated that irradiation of the head of rabbits destroys brain tissue without apparent injury to the skin.

The cause of death from abdominal irradiation is usually attributed to shock; in other words, the mechanism of death is not understood. It is postulated that tissues respond to heat denaturation with an aseptic inflammatory reaction and are, as a consequence, prone to infection. This in turn may lead to peritonitis and shock. Boysen studied whole body radiation in experimental animals, using a 350 megacycles microwave generator with a power output of 5 to 500 watts. He observed hyperemia, hemorrhage, and necrosis in the bowels of irradiated animals and found the jejunum and ileum particularly susceptible to microwave radiation. Hyperemia of the spleen and hemorrhage into the myocardium were also observed. In addition, bloodless diarrhea ensued in each instance.

Although the precise temperature at which injurious effects are first noted has not been determined for all tissues, it is known that it varied for different tissues. It is well known that the testes undergo degenerative changes when maintained for a considerable period of time at a temperature equal to that found in the abdominal cavity. Severe testicular damage has been produced in animals by microwave irradiation. Studies of the effects of 12 cm microwaves upon the testes of adult rats have shown that a single 10 minute exposure caused testicular degeneration at a temperature of only 35 C measured in the central area of the gland. No evidence of any damage to the epidermis was found despite the pathologic changes which occurred in the interior of the gonads.

Cataract production is a frequently reported microwave injury. Microwaves of about 10 cm tend to produce maximum heating in tissue about one cm below the irradiated surface. Studies by Richardson, et al, showed that rabbit eyes exposed for 15 minutes at a distance of 5 cm from a 100 watt source of 12 cm microwaves developed lesions of the eye resembling cataracts in 3 to 9 days after the exposure. A series of repeated exposures to a lower power level at the same frequency produced cataracts in from 2 to 42 days. These cataracts varied from small posterior polar masses to almost complete involvement of the lens. The thermal coagulation of the protein in the cells of the lens is believed to be responsible for formation of these lesions.

In studies carried out on rabbits irradiated with 12 cm microwaves, it was found that greater temperature increases occurred in tissue containing metal implants than in control tissues.

It is believed that the microwave radiation is reflected by the metal plate and that standing waves are set up in the tissues between the metal plate and the irradiated surface. The energies of the reflected wave are added to that of the original radiation so that a greater temperature increase occurs. The effect of a metal implant depends on the depth of the implant and the wave length of the microwaves. This may have significance to people with metal bone implants, metal plate covering a cranial defect, or retained wire sutures in the body. Such people may be quite vulnerable to tissue damage from exposure to microwave.

Injuries in Man. Studies by Daily and by Lipman and Cohn have shown no harmful effects of microwave irradiation to man. On the other hand, there are occasional reports of such injuries in the literature.

A case of bilateral cataracts in a 20-year old radar repairman was reported in 1952. A few months later, Hirsch and Parker reported similar lesions in a 32-year old technician who had operated a 100 watt microwave generator in the range of 9 to 18 cm for 11 months. This man was in the habit of placing his hands and head in the microwave antenna to determine whether the generator was operating. The lenticular opacities in this case resemble the nuclear type produced by microwaves in experimental animals. There was, in addition to the lenticular opacities, a choroiditis of the left eye that may have resulted from the microwave exposure.

McLaughlin, in 1957, reported a fatal case of accidental exposure to microwaves in a 42-year old white male. The validity of ascribing this fatality to microwaves has been vigorously protested. It has been denied that any exposure occurred, and further, that the cause of death was an ordinary ruptured appendix accompanied by generalized peritonitis. At this time, the McLaughlin findings are neither accepted nor rejected; the case is cited here chiefly to note that this is a matter of active controversy.

Although no permanent injury has been reported from microwave exposure of people with metal implants in their bodies, reversible physiologic changes have been described by Rieke. He reported a case of post-injury swelling in the hand of a 58-year old carpenter who had a stainless steel plate implanted in the proximal phalax of the left index finger for a compound fracture and whose hand and finger were supported by an aluminum splint. Following an uneventful postoperative course, the patient returned to work some 22 days after the injury and noted the onset of swelling and pain in the left hand which persisted and was unexplained in the next two weeks. He worked near a high frequency glue drying machine and it was later realized that he had been receiving unplanned diathermy owing to exposure to this radiation at work. The swelling and pain disappeared when he stayed away from the machine. In this case, the swelling and pain may be explained on the basis of heat induced in the steel plate and aluminum splint by absorption of the radiation energy. This phenomenon has been confirmed by the animal experiments described earlier.

Prevention of Injury. Increasing use and power of microwave equipment in the Armed Forces, in navigation, communications, and in medicine, and the possibility that microwave radiation may produce biologic injury indicate the wisdom of preventing inadvertent exposure to these radiations. People most liable to accidental exposure are those who operate or service high power radar equipment. The most obvious form of protection is to prevent people from entering radar beams. The radar beams should be pointed toward unoccupied areas when possible; metal screens may be used to shield out the radiation; lights may be installed to warn personnel that the radar set is on and to indicate the boundaries of the beam; people who work in the vicinity of radar equipment can be supplied with photographic flash bulbs to warn them when they are exposed to intense microwave fields. Perhaps people with metal implants in their bodies should be excluded from work with such equipment.

The potential hazards of microwave diathermy are considered by many to be much less than the hazards associated with radar equipment. The justification for this view is that the power output of the diathermy machines is so much smaller than that of radar equipment. This specious argument disregards the fact that it is not the power output of the device that determines its hazard, but rather the amount of energy that it deposits in tissue. The physical and biologic situation in tissue irradiated by microwaves to the extent that a temperature rise of 3 C is produced is the same whether the radiation is delivered by a diathermy machine or a radar transmitter. A backward glance to the once fashionable use of radium salts and x-rays may not be out of place.

In cases where microwave diathermy is considered to be the treatment of choice, such vulnerable organs as the testes and eyes can be protected by close-fitting metallic screens. Extreme care should be exercised in application of microwave diathermy to patients with metallic implants to prevent excessive heating and tissue damage.

Treatment. There is no suitable treatment once irreversible damage has occurred. Shock resulting from prolonged local body irradiation should be treated by maintenance of blood pressure with a vasopressor, infusion of blood or fluid, and supportive therapy. Should respiratory embarrassment be found as the result of whole body irradiation, artificial respiration and oxygen should be administered and a means for rapid cooling of the body provided. As yet there is insufficient clinical experience to prognosticate the course of this type of illness; therefore, any prognosis should be guarded in these patients until more is known about microwave radiation. (Kuo-Chiew Quan, Hazards of Microwave Radiations: Industr Med Surg, 29: 315-318, July 1960)

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Occupational Disease in California Attributed to Pesticides

Geographic Distribution. Reports of occupational illness attributed to pesticides and other agricultural chemicals came from 49 of California's 58 counties, nearly half from the following jurisdictions: Fresno, Los Angeles, and Tulare 10% each; Santa Clara 8%; and Kern 7%. Fresno, Los Angeles and Tulare are the three leading employers of agricultural labor with Fresno employing by far the largest number of workers. Kern and Santa Clara are in sixth and ninth place, respectively, as employers of agricultural labor.

The agricultural industry was responsible for most of the reports from counties having the greatest number of reports with the exception of Los Angeles. Only 21 of Los Angeles' 93 reports came from agriculture. Nearly two-thirds came from other industrial categories: manufacture 20 reports, government 18 reports, trade 13 reports, and service 10 reports.

Chemicals. The need to control the damage to crops by pests and diseases requires continuous research and manufacture of new materials. Every year the number of pesticides and other agricultural chemicals put on the market increases. All pesticides sold in California must be registered and the label must show the chemical or common name of the active ingredient as well as appropriate warnings and precautions.

The organic phosphate chemicals, with a few notable exceptions such as malathion, are among the most hazardous materials used as pesticides. Parathion, TEPP (tetraethyl pyrophosphate), Systox, and Phosdrin are highly toxic phosphate ester (more commonly called organic phosphate) chemicals. Organic phosphate chemicals may enter the body directly through the skin as well as by inhalation and swallowing. As a rule, workers should wear protective clothing when applying these chemicals.

The national production of the halogenated hydrocarbon pesticides is many times that of the organic phosphate pesticides. Nearly half the production of halogenated hydrocarbon pesticides is DDT (143,216,000 pounds), a still effective but relatively less hazardous insecticide. In addition to DDT, this group of pesticides includes chlordane, lindane, aldrin, dieldrin, and toxaphene. Most pesticides in this group are less toxic than the organic phosphates. Some insecticides are used in homes and gardens as well as for crop protection. DDT, chlordane, lindane, and malathion are among these.