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ANALYSIS OF OCCUPATIONAL EXPOSURE TO MICROWAVE RADIATION

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ABSTRACT

Principles of analysis of environmental conditions and of comparison of various microwave worker groups are discussed. Early and actual findings concerning the health status of microwave workers, published by various Polish authors, are compared and discussed in the light of personal experiences. Advantegous effects of safety rules enforcement may be documented by the comparison of results published actually and ten years ago.

Introduction

The present paper is an attempt to summarize briefly personal experience and that of our colleagues, who worked in close contact with us during the last sixteen years. All the comments, however, express personal opinions of the present authors only. The list of references was restricted to the essential minimum, as an almost complete list of pertinent papers can be easily had comparing the bibliographies in references 4, 12, 13, 23 and 28.

Analysis of occupational exposure to microwave radiation is fraught with many difficuties, the main being the assesement of the relationship between the microwave exposure levels and the health status of examined groups of workers. The possible role of other environmental factors and of socio-economic conditions must be taken into account. As it often happens in clinical work, it is difficult to demonstrate a causal relationship between a disease and the influence of environmental factors, at least in individual cases. Large groups must be observed to obtain statistically significant epidemiolo-

gical data. The problem of adequate control groups is controversial and hinges mostly on this, what one considers "adequate". All these questions must be discussed separately.

Analysis of Environmental Conditions

Precise quantitation of human exposure is possible only in the case of therapeutic or diagnostic applications of microwaves. In view of the lack of adequate instrumentation, especially of individual dosimeters, the quantitation of exposure during work is extremely doubtful. This is particularly the case where personnel moves around in the course of their duties and is exposed to non-stationary fields (moving beam or antenna of radars for example), as well as to near and far fields alternatively. It is impossible to evaluate the exposure over a period of several years within reasonable limits. Attempts to present detailed data as to the source of microwave radiation, effective area of irradiation, position of the body in respect to the field etc for an individual worker for a period of several years would be misleading to an extreme degree. In the present authors' opinion it is far better to present approximative evaluations, than to create an impression of accuraccy, where none can be had.

Gordon (13) divided the microwave exposed workers examined by her into 3 groups, according to exposure levels:

1. periodic exposure to "high energy density" levels i.e. 0.1 - 10 mW/cm2,
2. periodic exposure to "low energy density" levels i.e. 0.01 - 0.1 mW/m2,
3. systematic exposure to low energy density levels.

The first group consisted of technical maintenance personnel and workers of repair shops and certain factories (montage). This group could be called shortly as production, montage, technical maintenancw and repair of microwave equipment. It should be mentioned that a large part of this personnel was periodically exposed to fields of the near zone. The second group consisted of technical maintenance personnel as well as certain categories of personnel engaged in exploatation of microwave apparatus, research workers and others. The third group consisted of personnel engaged in the use of various microwave equipment, mainly radar stations.

In our investigations we adopted a similar rule of division of the persons examined into high, mean or low exposure groups, or later, into two groups - high and low exposure. In environmental conditions analyses such factors as air temperature, movement and humidity, noise, lighting and exposure to ionizing radiation generated incidentally by electronic equipment were taken into account. It should be stressed that exposure to these factors is casefully controlled, according to Polish laws.

Safe microwave exposure limits and regulations enforcing various safety measures and precautions were introduced in Poland in 1961. As in other countries, only gradual enforcement was possible. In view of this, all examinations of personnel carried out before 1962 concerned persons subjected to uncontrolled exposure. The possible exposure levels could be evaluated only ex post, and only approximately. In the period 1962 - 1968 data on exposure levels based on power density measurements and analysis of working conditions became available, most examined individuals had, however, a shorter or longer uncontrolled exposure history.

In view of this the publications concerning health status of personnel professionally exposed to microwaves may be divided into papers concerning:

1. persons having a history of longer or shorter periods of work under uncontrolled conditions, exposure levels undetermined or calculated (or rather guessed at) ex post;
2. persons with a history as above and a period of work in controlled environment;
3. persons examined before work was undertaken and working in controlled environment.

Numerous Polish papers concern the first and second groups (1, 6, 9, 10, 14, 16, 18, 22) or the second group and third groups jointly (3, 11, 15, 17, 19, 29) and only very few exclusively the third group (7, 8, 25, 26). All these findings, as well as additional unpublished data, served as a basis for determination of the new Polish safe exposure levels (7).

Early Investigations

Selected groups of microwave workers were first examined at intervals of 3 months, later 6 months and finally each year. All the persons examined were usually divided into 3 groups:

1. low level exposure of the order of tens of micro W/cm2 usually in far field conditions or in complex field in closed rooms where only very low power equipment was installed;
2. "mean" level exposures in far and near field zones, where no important non-intended radiation was expected, the measured and expected levels being of the order of hundreds of micro W/cm2 up to about 1 mW/cm2;
3. high level exposures of the order of mW/cm2 up to 10 mW/cm2, in certain instances even more.

No attempt was made to differentiate between exposures at various microwave frequencies, as most individuals available were exposed at this or other time over the whole microwave range. No adequate control group could be found because of difficulties in finding individuals working in sufficiently similar conditions (temperature, noise, humidity, time of day etc.) of work and being in sufficiently similar econo-

mic and social position, having similar everyday living habits and conditions, as well as belonging to the same age group. It was decided to analyse the material according to the total period of work within the group and according to the exposure level (between groups). Making the last type of analysis it was possible to collect such groups which were reasonably similar in all respects (socio-economical and psychological including) save the level of exposure.

All cases, where pathology related to any evident known etiology could be found, were excluded. Medical documentation on earlier examinations and physical check - ups was obtained in all cases and compared with actual findings. This documentation was nevertheless in most instances unsatisfactory in respect to age examination and laboratory data.

The results obtained confirmed the findings of USSR authors (13, 23, 28). Complaints were analogous and demonstrated a periodicity of occurrence in relation to the duration of occupational exposure, stressed in the Soviet literature (23).

The presence of complaints was characteristic for persons subjected to periods of uncontrolled exposure, before safety rules were introduced. Headackes and fatique unproportional to effort occured in 47% and 45% in group 3, in 30 and 34% in the group 2 and 30% and 30% in group 1 during the first year of work, disappear for two years, recurr during the period 3-5 years of work and may reapper in certain individuals after 5 or 10 years. Abnormal excessive sweating (during the night) has a similar time dependence and was found in 68.8% in group 3, in 33.4% in group 2 and in 22.5% in group 1 during the first year of work, in the period of 3-5 years of work, the respective values being 14.5%, 15% and 7%. Later on this symptom was not observed. Changes in blood pressure occurred only in group 3, the percent of hypotonia being 18 during the first year, 14 in the period 1-3 years, 6 in the period 3-5 years, 8 in the period 5-10 years and 11 over 10 years of work. In the remaining groups this percentage was less than 1. It should be added that no correlation with changes in heart beat rate could be demonstrated.

T he peripheral blood picture did not demonstrate any abnormalities. In group 1 diversified WBC resposenses were seen during the first year of work. After ten years of work in the same group 10.5% of workers shows absolute lymphocytosis usually accompanied by monocytosis, the total WBC being over 10,000 per mm3.

Neurological examinations are difficult to evaluate. Many of the physicians, who carried out these examinations, differed in the evaluation of reflexes, demographism, signs of irritability etc. In view at this the only means of obtaining objective results are electroencephalographic studies. These do not demonstrate any abnormalities in group 1. In groups 2 and 3 depending on duration of work and degree of exposure,

a definite decrease in the number and amplitude of alpha waves occurs. Theta and delta waves and spike discharges may occur. The response to photostimulation is decreased. The most impressive finding is the poorly expressed bioelectric activity after more than 5 and even more so 10 years of work.

It should be stressed that a rather specific phenomenon occurs in microwave workers (3, 11). Intravenous administration of cardiazole (metrazole) may be used for provocation of discharges (preconvulsive discharges) in the EEG, convulsions or shock. According to literature this phenomenon is dose dependent and a cardiazole threshold exists, the doses of 7 mg/kg body weight remaining without any effect. Intravenous administration of 500 mg cardiazole in 10 ml (1 ml/30 s with 30 s intervals) does not prowoke any effects in a normal adult male. In microwave workers of over 3 years of exposure theta waves, theta discharges, spike discharges and even convulsions occurred. 12 persons were examined, in 8 the test could not be completed. The study was discontinued, as the test was considered dangerous for the patient. It should be pointed out that this phenomenon was studied extensively in rabbits (2, 3), and a decrease of cardiazole tolerance in irradiated animals may be considered as established.

Cases of what was considered a "microwave sickness" svere reported in Polish literature (5, 6). It may be doubted if a specific nosologic entity may convincingly demonstrated in the present state of understanding of microwave bio-effects.

In the course of work connected with health surveillance and risk analysis, the present authors encountered "clusters" of certain deviations from normal in factories or other working places, where exposure levels were exceptionally high i.e. about 10 mW/cm2 or more during about 1 hr/day. In such places also exposure to non-intended radiation could be expected. The abnormalities consisted in the presence of 0.5-2% of otherwise healthy persons with deep bradycardia (less than 50/min) and signs of impairment of heart conductivity in the ECG, various percent of workers with stomach ulcers or peripheral blood picture changes (slight anemia, lymphocytosis or granulocytopenia or persisting unexplained granulocytosis). Such groups were usually too small to draw any valid conclusions, so only an impression remains that working conditions had "something to do" with these phenomena. This impression is strenghtened by the fact that after introduction of rigorous health and exposure surveillance, as well as partial exchange of personnel, no further cases were noted.

It should be added that no cases of "microwave cataracts" were described in Polish literature or found be us. A higher incidence of lenticular opacities was reported in groups with histories of uncontrolled exposure periods and may possibly occur in poorly controlled exposure conditions (14, 16, 29).

Actual Findings

A special study was undertaken on to determine if work under conditions conforming to actual Polish safe exposure limits (24) may be considered as truly safe. Detailed results are to be published shortly in English (8, 25, 26), and in view of that the results will be presented very briefly.

An analysis of the incidence of disorders considered contraindications for occupational microwave exposure among 841 males aged 20 to 45 years and exposed occupationally to microwaves for various periods was made. The analysed population was subdivided into two groups differing only in respect to microwave exposure - low i.e. below 0.2 mW/cm2 and high i.e. between 0.2 mW/cm2 and 6 mW/cm2. No dependence of the incidence if disorders considered contraindications for occupational microwave exposure on the exposure level or duration of occupational exposure could be demonstrated (8). The incidence of lentieular opacities was compared between both these groups, as well as analysed within each group, subdivided according to age or duration of occupational exposure. No dependence of the incidence of lenticular opacities on the exposure level, nor on duration of occupational exposure was found. Significant correlation with age was demonstrated (26).

The incidence of functional disturbances (neurotic syndrome, gastro-intestinal tract disturbances, cardio-circulatory disturbances with abnormal ECG) was also analysed and no dependence on the exposure level or duration of occupational exposure (years) could be demonstrated (25).

Conclusions

Uncontrolled professional exposure leads to the appearance of vegetative and central nervous disturbances, asthenic syndromes and such like chronic (prolonged exposure) effects, which are well documented by early Soviet, Polish and Tchech reports; the pathogenesis of these syndroms may be denied, similar observations were made by Miro (21) in France and in the United Kingdom and USA, according to a personal communication made by Munford to Seth and Michaelson.

Controlled professional exposure of healthy adults seems to have no untoward effects if the (new) Polish safe exposure limits (24) or even more so the conservative Soviet ones (23) are observed.

The last point, which is most important and cannot be sufficiently emphasized, is that all available data concern healthy human adult exposure, mostly men. The effects of intermittent or continous exposure of children living near radar installations or TV transmitters is completely unexplored. Children may be expected, because of body size and geometry,

to absorb microwave energy differently from adults. Exposures to 4-8 min/day microwave irradiation at low mean (tens or hundreds microwatts per sqcm), and very high peak power densities are sufficiently real for children, as to cause concern.

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