

## Session E. Occupational Exposure and Public Health Aspects of Microwave Radiation

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### CLINICAL MANIFESTATIONS OF REACTIONS TO MICROWAVE IRRADIATION IN VARIOUS OCCUPATIONAL GROUPS

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Studies on the biological action of microwaves have been widely conducted in the USSR over the past 20 years. The investigations have been devoted mainly to hygienic, experimental, clinical and ecological aspects of the problem. Studies are being performed in the USA, Poland, Czechoslovakia, and in Western Europe (21, 22, 23, 24).

Results of our own clinical observations of many years, as well as literature data (2, 5, 6, 9, 12, 18, 22, 23) show that, as a consequence of prolonged work involving exposure to microwaves, changes take place in the functions of the nervous, cardiovascular and other systems of the organism leading to a characteristic complex of symptoms. A distinct form of occupational disease — microwave or radiowave sickness — has been identified as a nosologic entity.

However, up till now, numerous questions concerning the clinical course and pathogenesis of certain lesions have been insufficiently elucidated.

The present communication presents clinical observations on the health status in two groups of workers engaged in the regulation, tuning and testing of diverse radio-equipment emitting radiation in the microwave range.

Both groups were comparable with respect to sex and age, but differed in intensity of exposure and duration of work. Young men with a long (5—15 years) history of employment with microwave sources predominated in both groups. Those in the first group (1000) were subject to the influence of a power density of up to a few mW/cm<sup>2</sup>. The second group (180) comprised people exposed to microwaves at lower

intensities, which as a rule did not exceed several hundredths of a mW/cm<sup>2</sup>. More significant exposure could have taken place during extremely short periods.

Some nervous tension during work could not be excluded. A group of people (200), matched with respect to sex, age and character of work processes which did not involve exposure to microwaves, served as a control.

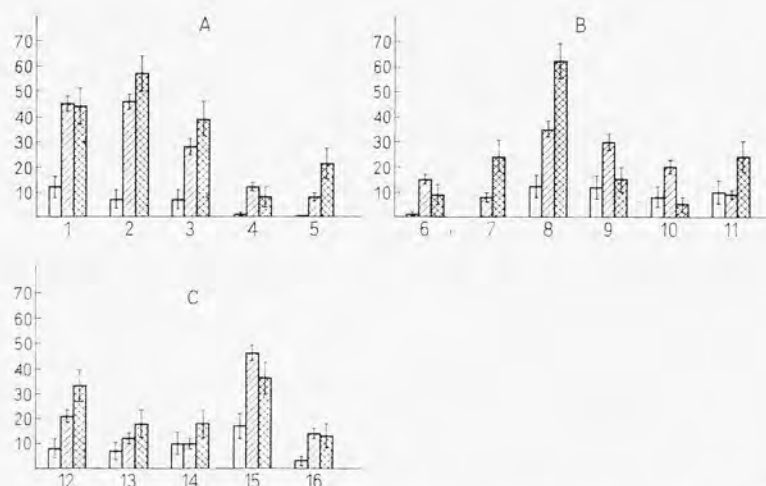


Fig. 1. Changes in the nervous and cardiovascular systems among workers exposed to microwaves and control subjects. Ordinate — frequency of changes in percentages; abscissa — main indicators: A — neurological, B — autonomic vascular and C — cardiac. White columns — control; oblique shading — persons of the first group, exposed previously to periodic action of microwaves of substantial intensities; double shading — persons of the second group working under conditions of exposure to microwaves of lower intensities. All indicators are presented with confidence limits. 1 — feeling of heaviness in the head, 2 — tiredness, 3 — irritability, 4 — sleepiness, 5 — partial loss of memory, 6 — inhibited dermographism, 7 — expressed dermographism, 8 — hyperhidrosis, 9 — bradycardia (upon counting), 10 — arterial hypotension, 11 — arterial hypertension, 12 — cardiac pain, 13 — dullness of the heart sounds, 14 — systolic murmur, 15 — bradycardia (according to ECG), 16 — lowering of deflections T I and T II.

Figures 1 and 2 show the frequency of the main subjective and objective changes in the subjects examined, as well as the relationship of these changes to duration of work under given conditions.

Inspection of Figure 1 shows that people of the first and second group significantly differed from the control in frequency of such complaints as heaviness in the head, tiredness, irritability, drowsiness during the day, anxiety and light sleep at night and partial loss of memory. In both groups attention was drawn to various autonomic vascular changes: inhibited or expressed dermographism, hyperhidrosis of the hands, instability of pulse and arterial pressure increasing during functional loading (orthoclinostatic test, Aschner's test, graded physical loading), tendency to bradycardia (pulse rate of up to 60 per min) and arterial hypotension (systolic pressure of up to 100 mm Hg) or hypertension (systolic pressure of more than 135 mm Hg) appearing against the background of normal arterial pressure and accompanied by narrowing of retinal arteries (1).

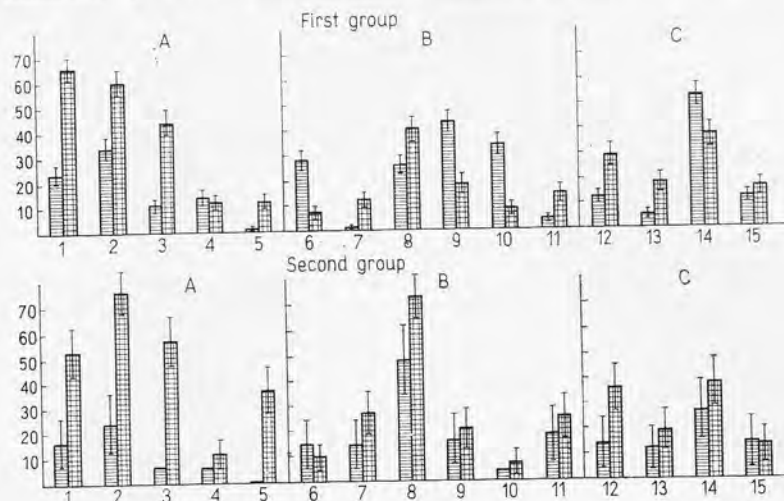


Fig. 2. Changes in the nervous and cardiovascular systems among those under 40 with varying duration of work involving exposure to microwave irradiation. Ordinate — frequency of changes in percentages, abscissa — main indicators: A — neurological, B — autonomic vascular and C — cardiac. Horizontal shading — duration of employment of less than 5 years; double shading — duration of employment of 5—10 years. First group — persons exposed previously to periodic exposure to microwaves of substantial intensities; second group — those working under conditions of exposure to microwaves of lower intensities. All indicators are presented with confidence limits. 1 — feeling of heaviness in the head, 2 — tiredness, 3 — irritability, 4 — sleepiness, 5 — partial loss of memory, 6 — inhibited dermographism, 7 — expressed dermographism, 8 — hyperhidrosis, 9 — bradycardia (upon counting), 10 — arterial hypotension, 11 — arterial hypertension, 12 — cardiac pain, 13 — dullness of the heart sounds, 14 — bradycardia (according to the ECG), 15 — lowering of deflections T I and T II.

Functional thyroid changes with increase of its activity occurred not infrequently (15).

Predominant complaints concerned cardiac pain of a lancinating or boring, and less frequently constricting, character radiating to the scapula and arm. The heart sounds were dull and functional systolic murmur over the heart apex was present.

Electrocardiographic examination revealed minor disturbances of intraventricular conduction (conduction of the initial part of the ventricular complex amounted to 0.10 s or 0.11 s and more), sinus bradycardia and moderate lowering of T deflection in standard leads. In some cases more pronounced changes of T deflection were observed (lowered, smoothed or negative T deflection) in left chest leads, accompanied by minor downward displacement of the S—T segment without conspicuous changes in its shape, and by increased duration of electric ventricular systole. In a number of cases these changes in T deflection were combined with bradycardia and deceleration of intraventricular conduction which, taken together with complaints of heart pain and hypertensive reactions, led to their being taken for myocardial lesions or manifestations of coronary spasm (4, 12).

Autonomic vascular changes in persons of the first group exposed periodically in the past to microwaves of high intensities had vagotonic, as well as sympathicotonic, character, while in the second group they were predominantly sympathicotonic.

In both groups (Fig. 2) the frequency of asthenic and autonomic vascular disturbances of a hyperreactive character (expressed dermographism, hyperhidrosis, arterial hypertension) related to age and employment depended directly on the duration of professional contact. Among those working for 5—10 years reactions of this type predominated in the second group, but they were more pronounced in the first one. As to vagotonic reactions (inhibited dermographism, bradycardia, arterial hypotension), they occurred mainly in the first group in the initial period of work with microwave sources.

The above data showed that microwave action was characterized by autonomic vascular symptoms of a vagotonic character. At the same time the symptoms of dystonia of the hypertonic type, related to nonspecific regulatory shifts, were less clearly related to intensity of action. Their etiology and clinical significance require further verification.

Only minor changes were found in the peripheral blood in both groups (16, 17). Some decrease in mean erythrocyte count was found ( $4\ 600\ 000 \pm 0.18$  and  $4\ 600\ 000 \pm 0.031$  in the first and second group, respectively), as compared with controls ( $4\ 700\ 000 \pm 0.17$ ). Slight thrombocytopenia occurred in the first ( $221\ 500 \pm 2.53$ ) and second ( $216\ 300 \pm 4.13$ ) groups; controls:  $245\ 000 \pm 1.6$ . Moderate leukopenia was found in the first group ( $5\ 930 \pm 0.065$ ); controls:  $6\ 490 \pm 0.058$ . In a number of cases leukocytosis was encountered in the initial period of professional contact.

A tendency to cytopenia was observed predominantly in the first group with longer duration of employment. These people showed signs of a qualitative deterioration of erythrocytes, with a tendency to spherocytosis and an increase in acid fragility. Decreased numbers of mature cells of the neutrophilic series and signs of stimulated erythropoiesis were noted in bone marrow smears. Examination of ordinary bone marrow smears and of metaphase plates did not reveal an increased frequency of chromosome aberrations by comparison with controls.

Examination of deep refracting media of the eye revealed opacities of the crystalline lens as viewed in the slit lamp (1). Opacities were distributed mainly in the cortical layer and in superficial layers of the mature nucleus along its equator, and only single ones were found in the centre. Their frequency did not exceed control values. However, with increasing duration of occupational exposure the opacities of the lenses progressed. In a few cases the subjects of the first group working in unfavourable conditions developed cataracts with opacities of the crystalline lens detectable even in transmitted light.

In the majority of those examined single abnormalities in their health status did not interfere with the usual rhythm of life and work.

In a number of cases the abnormalities combined into a complex of symptoms which required therapeutic intervention.

Upon close examination in the ward a complex of symptoms corresponding to microwave sickness was diagnosed only in those patients of the first group who began their work under the most unfavourable conditions. Its frequency in the whole group did not exceed 15%.

We showed previously (4, 7, 13) that the clinical picture of microwave sickness was characterized by a complex of various autonomic vascular disturbances with crises of cerebral and coronary vascular insufficiency and asthenic symptoms. We distinguished three stages in the development of the sickness according to criteria generally accepted by pathologists: initial (I), moderately advanced (II) and advanced (III) with the following main clinical syndromes: asthenic, astheno-autonomic with vascular dysfunction of hypertonic type, and hypothalamic (autonomic vascular form).

The asthenic syndrome occurred in the initial stages of the disease. It included mainly a complex of asthenic symptoms dominated by autonomic vascular changes with a vagotonic tendency.

The syndrome as a whole took a benign course.

The astheno-autonomic syndrome with vascular dysfunction of the hypertonic type was most frequent and occurred largely in moderately advanced and advanced stages of the disease.

In the clinical picture of a given syndrome, with the background of deepened asthenic phenomena, of primary importance were the autonomic disturbances related to increased excitability of the sympathetic division of the autonomic nervous system as well as vascular instability with hypertensive and angiospastic reactions. The latter frequently determined the severity of the illness.

At a certain stage of development of autonomic vascular disturbances the hypothalamic syndrome (autonomic vascular form) appeared and was characterized by sudden crises, predominantly of a sympathico-adrenal character.

The astheno-autonomic and hypothalamic syndromes took a protracted course. In advanced stages of the disease the asthenic, emotional and autonomic vascular disturbances and crises became more pronounced. In a number of patients the clinical picture of ischaemic heart disease and hypertension developed; the latter was frequently of the cerebral type.

Angiospastic symptoms were confirmed by the results of rheographic examinations of brain hemodynamics which showed a lowered intensity of pulse blood flow and predominantly an increased tonus of intra- and extracranial vessels which was restored under the influence of the nitroglycerine test (14).

Data of mechanocardiographic investigations showed increased tension-relaxation changes of vessels of the muscular type and increased peripheral resistance (4, 11).

Similar changes in the cardiovascular system were observed by a number of investigators (8, 10, 19, 20).

Electrocardiographic changes (3) and abnormal findings in some biochemical tests (13) correlated with the clinical observations.

In the initial stages of the disease electroencephalograms of the patients disclosed changes in alpha activity, stable alpha rhythm or decreased amplitude of alpha waves. In moderately advanced and advanced stages, bilateral synchronous discharges of theta- and delta-waves were found, and sometimes diffuse slow oscillations most clearly seen on hyperventilation, thus showing that subcortical structures were involved in the pathological process.

In the early period changes in protein composition took place, as evident from increase in total serum proteins, dysproteinemia and lowered albumin-globulin ratio.

Changes in the sugar curve after glucose loading — flattening (1st type), so-called diabetic (2nd) type, sometimes of biphasic character — accompanied all clinical forms of the disease, but they predominated in neurocirculatory disturbances with crises.

Some increase in cholesterol level, lowered lecithin-cholesterol ratio and decrease in blood chlorides were seen. Some authors (8, 10) have reported dysproteinemia, dyselectrolytemia and changes in blood lipid levels.

In moderately advanced and advanced stages of the disease catecholamine excretion was changed and the epinephrine-norepinephrine ratio was lowered, although the content of these amines in daily urine collections was normal. A few patients during crises exhibited sharp fluctuations of epinephrine levels, as well as an unusual daily rhythm of norepinephrine, excretion, the latter characterized by increase in the evening and at night.

Certain abnormalities in glucocorticoid metabolism were found: the overall index was

lowered and the ratios of discrete fractions were changed. Changes in catecholamine excretion and in metabolism of glucocorticoid hormones were more marked after epinephrine loading which led to development of clinical autonomic vascular reactions.

The above investigations confirmed the clinical and electroencephalographic observations showing that deep, and particularly hypothalamic, structures of the brain were involved in pathological processes. Dysfunction of the hypothalamus, hypophysis and suprarenals, appearing against a background of asthenic phenomena, could be of importance in the pathogenetic mechanisms of development of the clinical symptoms of microwave sickness.

Investigations (Tab. 1) of those patients suffering from microwave sickness of one to ten years' duration (3—6 years in the majority of cases) showed that, despite repeated

Table 1  
Clinical course of microwave radiation sickness during and after exposure

| Clinical syndromes                              | Period of observation* | No. of cases | Clinical course** |               |               |
|---|------------------------|--------------|-------------------|---------------|---------------|
|   |                        |              | Recovery          | Stabilization | Progression   |
| Asthenic  | A                      | 24           | —                 | 13<br>54 ± 10 | 11<br>47 ± 10 |
|   | B                      | 5            | 3<br>60 ± 24      | 2<br>40 ± 24  | —             |
| Asthenic-autonomic<br>with vascular dysfunction | A                      | 47           | —                 | —             | 47<br>100 ± 2 |
|   | B                      | 16           | —                 | 15<br>94 ± 6  | 1<br>6 ± 6    |
| Hypothalamic (auto-<br>nomic vascular form)     | A                      | 2            | —                 | —             | 2<br>100      |
|   | B                      | 6            | —                 | 5<br>83 ± 17  | 1<br>17 ± 17  |
| Total   |                        | 100          | 3<br>3 ± 2        | 35<br>35 ± 5  | 62<br>62 ± 5  |

\* A — during employment under conditions of microwave exposure

B — after cessation of exposure to microwaves

\*\* Above, number of cases; below, percentage ± S.E.

therapeutic courses and temporary withdrawal from work with microwave sources, upon returning to previous work conditions symptoms increased in severity, particularly among patients with moderately advanced and advanced stages of the disease. In such patients autonomic vascular disturbances dominated, crises of cerebral and coronary insufficiency progressed and development of ischaemic heart disease and hypertension was observed.

Cessation of work involving irradiation frequently resulted in stabilization of the processes, or even recovery, if withdrawal took place in the initial stage of the illness

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