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AN EXAMINATION OF CERTAIN BLOOD SERUM CONSTITUENTS IN THE RAT FOLLOWING MICROWAVE IRRADIATION

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SUMMARY

Automated analyses of 12 blood serum constituents were performed after 6 groups of 3 rats each were subjected to pulsed irradiation for 15 minutes at one of the following power field densities (mw/cm^2): 5, 10, 20, 50 or 100; frequency = 2,860 MHz for all levels; pulse width = 1 μsec; repetition rate = 500 Hz. At 100 mw/cm^2 significant differences were observed in the albumin and phosphorus contents of the serum when compared to the control animals. Body temperature was noted to increase significantly only at field intensities levels of 50 mw/cm^2 or more. No significant difference in any of the measured parameters at 50 mw/cm^2 or below was observed when compared to the control group. Only at 100 mw/cm^2, where significant heat stress was noted, were any changes observed in any measured blood serum constituents. It is concluded that microwave irradiation (at 500 mw/cm^2 or below) has no significant effect on the blood serum parameters measured under the conditions of this study.

A second study was conducted using adult, male, NMRI:0 (Sprague-Dawley) rats, to determine the effect of pulse modulated microwave irradiation for 30 minutes (5 mw/cm^2; F = 2,860 MHz and 9,430 MHz, pulse width = 1 μsec, repetition rate = 500 MHz) on whole blood glucose levels. No differences in blood glucose levels were observed between irradiated and control (sham-irradiated) animals.

Key Words

microwave
serum proteins
glucose
radiation

The opinions or assertions contained herein are the private ones of the authors and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large. The experiments reported herein were conducted according to the principles enunciated in the Guide for Laboratory Animal Facilities and Care, prepared by the Committee on the Guide for Laboratory Animal Resources NAS-NRC.

INTRODUCTION

Blood Studies: Many authors have studied the effect of low level microwave irradiation on the blood system. The great majority of these reports are either in conflict, or written deleting important details concerning the irradiation procedure. These reports have been recently reviewed (McLees and Finch, 1971).

Various workers have reported that microwave irradiation causes marked changes in carbohydrate metabolism. For example, blood sugar levels of rabbits rose 30-60% following exposure of the upper abdomen to microwave and radio frequency (RF) radiation having wavelengths (λ) = 12.5 centimeters and 11 meters, respectively. When only the head of the rabbit was irradiated, blood sugar levels rose 90-100% above normal (Schliephake, 1960).

Syngayeveskaya et al. (1962) have reported that blood sugar levels rose 18-36% within 15-20 minutes after termination of exposure of rabbits to centimetric, decimetric and metric waves (Power Field Density (PFD) = 1-3 mw/cm^2, exposure = 20-30 minutes). According to these authors, there was no resultant temperature rise associated with exposure.

Gershman (1971) observed, in rabbits irradiated with pulsed 5,850 MHz and continuous wave 2,450 MHz, no significant differences in the serum protein levels when compared to sham-irradiated animals.

Nikogosyan (1962) reported a decrease in the albumin content and an increase in the γ-globulins in the blood serum of rabbits following 10 microwave treatments lasting 1 hour each (centimetric and decimetric bands, PFD = 10 mw/cm^2). No changes in the rectal temperatures of the animals were observed following irradiation.

Gruszeski (1962) has described a decrease in the γ-globulin and an increase in the α- and β-globulins of the blood serum of microwave-irradiated animals (λ = 3 centimeters, PFD = 100 mw/cm^2).

The aforementioned reports represent only a sampling of the varied and contrasting data presented on the effects of microwave irradiation on blood chemistry. It was with these reports in mind that the two experiments presented in this paper were conducted.

MATERIALS AND METHODS

Experiment I. This study was conducted using male rats, NMRI:O(SD), a Sprague-Dawley-derived strain, weighing between 400-450 grams. All animals were maintained, ad libitum, on a standard laboratory rat diet (D and G Laboratories). Experimental animals were irradiated for one, 15 minute period prior to blood sampling. All animals, experimental and control, were confined in plexiglas cages during irradiation or sham-irradiation.

The irradiation protocol for this experiment is illustrated in Table 1. The irradiation source consisted of magnetrons driven by a Manson Laboratory Pulse-Tube Modulator; for this study the modulator was set to deliver 1 μsec. pulses at a repetition rate of 500 Hz.

For S-band irradiation at 2,860 MHz a Raytheon model 4J31 magnetron was employed; this tube can deliver 900 kw of peak power and 600 watts of average power. A model 3030, Litton Industries X-band Magnetron was utilized in Experiment II as a source of 9,430 MHz radiation; the maximum output of this magnetron is 300 kw peak power and average power of 240 watts.

The output of the magnetron tubes was delivered to standard gain Narda horn antennas via the appropriate waveguide. Waveguide directional couplers used in conjunction with a Hewlett Packard Model 432 power meter allowed accurate forward power measurements. The output of the couplers could also be directed to a Polarad Model SA-84 WA spectrum analyzer to determine frequency and modulation parameters accurately.

The two horn antennas were located in one end of an anechoic chamber; this enclosure consisted of a screen room (7 1/2' high x 7' wide x 12' long) lined with microwave absorbing material. The two horn antennas were situated one-above-the-other in such a way that there was no interference between them. The entire system (i.e., magnetron, waveguide, antennas, etc.) was arranged so that conversion from S-band to X-band or vice versa took only a few minutes.

All animal irradiations in this study were conducted in the <u>far field</u> of the respective antennas. Power field density measurements were made with a Ramcor Model 1200 Densiometer. This instrument was calibrated against a Narda model 8100 meter in a 2,450 MHz continuous wave field; the continuous wave source consisted of a TWT amplifier available in the laboratory.

Since the Ramcor meter is a hand-held device it was necessary to enter the chamber while the source was turned on. Care was taken to avoid human exposures to fields in excess of 10 mw/cm^2. This prevented direct measurements of the 50 and 100 mw/cm^2 fields used in this study; therefore, accurate correlations were made between the field densities at 10 mw/cm^2 and below and the corresponding forward power measurement from the Hewlett Packard power meter. Higher field densities were then set by extrapolating linearly to higher forward power values. It is estimated that this procedure introduces no more than a 5% inaccuracy in the 50 and 100 mw/cm^2 field densities.

Following anesthetic etherization, blood samples were collected via direct cardiac puncture at the times postirradiation indicated in Table 1. The cardiac puncture technique was used in order to obtain a sufficient volume of blood for analyses of the serum parameters tested.

All serum analyses were conducted using the SMA-12 apparatus at the Clinical Chemistry Lab, Bethesda Naval Hospital. The following serum constituents were measured: total protein, albumin, globulin (by difference),

calcium, phosphorus, cholesterol (total), urea nitrogen, uric acid, creatinine, bilirubin (total) and glutamic-oxalacetic transaminase. The serum samples were analyzed the same day the experiment was conducted.

Rectal temperatures were monitored for all animals within 2 minutes postirradiation using an electronic thermometer (Digital-5); accuracy $\pm$ .01°F).

Experiment II. This experiment was conducted to determine the effect of microwave irradiation (at frequency levels of 2,860 MHz and 9,430 MHz) on blood glucose levels in laboratory rats. Male rats, NMRI:0 (Sprague-Dawley), weighing 350-370 grams each were used. All experimental animals were fasted 18 hours prior to irradiation and blood drawing. Rectal temperatures were monitored following irradiation.

Whole blood samples were collected via direct cardiac puncture after anesthetizing the animals with ether (Table 2). The blood samples were placed in heparinized tubes and analyzed on the day of irradiation. Blood glucose values were obtained using the automated glucose determination apparatus at the Clinical Chemistry Lab, Bethesda Naval Hospital.

RESULTS

Two separate experiments were conducted to determine the effect of low frequency microwave irradiation on certain blood constituents of laboratory rats.

Experiment I clearly illustrates that 15 minute exposure to PFD levels of 50 mw/cm^2 or lower has little or no effect on certain blood constituent levels. However, slight changes were observed following a 100 mw/cm^2 exposure; these changes were reflected in only the albumin and phosphorus levels (Table 3).

Rectal temperatures of the rats exposed to 50 and 100 mw/cm^2 were shown to differ significantly from the control animals (Table 4). No significant rectal temperature increases were noted at PFD levels of 20 mw/cm^2 or below.

The results of Experiment II show that short-term irradiation of rats at (5 mw/cm^2; F = 2,860 MHz and 9,430 MHz) causes no significant change in whole blood glucose level, when compared to sham-irradiated animals (Table 5).

Discussion: Because of the varied and contradictory reports concerning the effects of microwaves on certain blood constituents it was concluded that any well-designed experiment, using sufficient numbers of animals for statistical analyses, would be of value. The two experiments contained in this report were designed primarily as pilot studies to detect any effects of microwave radiation on blood chemistry.

Since no effects due to low level microwave irradiation on any of the blood parameters measured were observed the results of these pulsed S-band and X-band experiments using rats closely parallel the continuous wave S-band and pulsed C-band studies of Gershman (1971). He found, after low-level irradiation, rabbits showed no significant change in total serum protein, albumin or albumin/globulin ratio.

Gershman has also stated that the SMA-12 assays reflect with some degree of sensitivity the functional status of both the hepatic and renal systems.

Since there were no significant changes observed in the SMA-12 assays below microwave levels which tend to heat stress the animal, it is concluded that low-level microwave irradiation, under the conditions presented in this study, has little or no significant effect on those blood parameters measured.

The changes observed in the group irradiated at 100 mw/cm^2 indicate strongly that heat stress, due to the irradiation, may be the cause of the observed differences.

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TABLES

TABLE 1. Experimental Protocol (Experiment I)

Number of Animals	*Power field Intensity (mw/cm^2)	[t]Blood sampling times postirradiation (min.)
3	5	[t]5, 10, 15
3	10	5, 10, 15
3	20	5, 10, 15
3	50	5, 10, 15
3	100	5, 10, 15
3	(0) Control	5, 10, 15

*S-band pulse modulated irradiation, F = 2,860 MHz, pulse width = 1 μsec, pulse repetition rate = 500 Hz.

[t]One animal sampled per time per group.

TABLE 2. Experimental Protocol (Experiment II)

		†Control	‡Irradiated I 5 mw/cm^2; F = 2,860 MHz	‡Irradiated II 5 mw/cm^2; F = 9,430 MHz
Time (min.) Postirradiation	5	1*	1	1
	15	1	1	1
	30	1	1	1
	60	1	1	1
	90	1	1	1

†Control animals were sham-irradiated.

*Number of animals sampled.

‡Modulator parameters: pulse width = 1 μsec, pulse repetition rate = 500 MHz.

TABLE 3. Average Blood Serum Values from Experiment I

	Animals/ Group	Total Protein (gms%)	Albumin (gm%)	Total Globulin (gm%)	A/G Ratio	Calcium (mg%)	Phosphorus (mg%)	Total Cholesterol	Blood Urea Nitrogen (mg%)	Uric Acid (mg%)	Creatinine (mg%)	Bilirubin (mg%)	SGOT (μ/ml)
Control	3	6.2	3.30	2.90	1.15	10.6	7.6	69	16	1.6	0.3	0.1	141
5 mw/cm^2	3	6.0	3.06	2.94	1.04	10.5	7.9	66	19	2.1	0.5	0.1	192
10 mw/cm^2	3	5.7	3.19	2.51	1.26	10.1	7.1	67	19	1.6	0.4	0.1	164
20 mw/cm^2	3	6.1	3.22	2.88	1.13	10.2	7.2	67	18	1.2	0.4	0.1	145
50 mw/cm^2	3	6.4	3.52	2.88	1.22	10.6	7.3	73	17	1.8	0.3	0.0	138
100 mw/cm^2	3	7.1	*4.02	3.19	1.28	10.3	*6.4	77	21	2.9	0.4	0.2	184

*Significantly different from control @ 1% significance level, using student-t-test.

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TABLE 4. Average Rectal Temperatures of Rats Taken Within 2 Minutes After Irradiation (Experiment I)

Treatment	Rectal Temperature °F
Control	96.13
5 mw/cm^2	96.70
10 mw/cm^2	96.47
20 mw/cm^2	97.37
50 mw/cm^2	*98.53
100 mw/cm^2	*102.13

*Significantly different from control (@ 1% significance level, using student-t-test).

TABLE 5. Glucose (mg%) Values (Experiment II)

			Irradiated I	Irradiated II
		Controls	5 mw/cm^2;F=2860 MHz	5 mw/cm^2;F=9430 MHz
Minutes	5	110	108	112
Post-	15	106	106	104
Irradiation	30	98	112	108
	60	126	124	122
	90	116	96	114