Biophysical and Biological Studies on the Effect of Electromagnetic Field on the Ehrlich Tumor Cells Implanted In Mice

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Abstract. A study of the growth retardation of liquid tumor cells (Ehrlich tumor) implanted in female mice by employing extremely low frequency electromagnetic field ELF-EMF (50 Hz, 2 mT) has been carried out for continuous exposure periods 20 and 40 days. Seventy two female BALB/c mice were used. They were equally divided into 4 groups: kept as control, groups 1 and 2, implanted intraperitoneally "I/P" with $2x10^6$ Ehrlich ascites tumor cells (EATC) groups 3 and 4 as single dose. Groups 2 and 4 were exposed to EMF for a period of 40 days. Two blood samples were collected after 20 and 40 days for hematological and biochemical examinations. Two samples of tumor cells were used for electrophoresis examination. The results showed that I/P implantation of EATC (group 3) resulted in relative polycythemia; leucocytosis with neutrophilia and a significant increase in the liver and kidney function indicators (bilirubin, α-fetoprotein, AST, ALT, BUN, creatinine, uric acid, inorganic phosphorus and sodium) while the serum total proteins, calcium and potassium levels were significantly decreased. The present results show that exposing the mice (group 4) to EMF they near the control ones. The results of protein electrophoresis revealed not only a decrease in the protein content of the Ehrlich tumor, but also considerable changes in its molecular structure as a result of exposing to 20 or 40 days of EMF. Such a decrease was found to be proportional to the exposure periods. Early treatment of the tumor cells by extremely low frequency electromagnetic field gave better results.
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1. Introduction

There have been considerable concern and controversy recently about the effects on health from the increasing exposure of populations to extremely low frequency electromagnetic field (ELF-EMF), [30,6]. These concerns have centered principally on childhood cancer (leukemia), but other diseases have been similarly implicated [46]. It is generally accepted that EMFs can exert biological effects; they have been widely used in clinical practice to processes such as neural regeneration [43, 45], wound healing [3,5] bone repair [2,26,8], The effects of weak magnetic and electromagnetic fields in biology have been intensively studied on animals, micro-organisms and humans, but comparably less on plants. From scientific literature, it is known that biological systems give different bio-responses to extremely low frequency magnetic field exposures at different frequencies and intensities. Various living organisms are differently affected from an extremely low frequency magnetic field, and these effects vary according to exposure conditions, genotype of organisms and the biological system. In this way, several such studies have suggested [7,12,35,55] that exposure to magnetic fields induces quite a variety of biological effects and, moreover, knowledge of the effects on living organisms is still not very clear.

One of the reasons could be the absence of a recognized common mechanism for EMF-bio effects. EMF is, in principle, capable of inducing selective changes in the microenvironment around and within the cell, as well as the cell membrane [50]. The cell membrane could be the site of action of low level EMFs by altering the rate of binding of calcium ions to specific membrane receptors [34]. Any change in the electrochemical microenvironment of the cell can cause modifications in the structure of its electrically polarized membrane by changing the concentration of a specifically bound ion or dipole that may be accompanied by alterations in the conformation of lipids, proteins and enzymes, [5]. Therefore, even small alterations in the trans membrane potential could trigger a significant modulation of cell function [42].

Electromagnetic forces applied on the membrane outer surface could modify ligand-receptor interactions, which in turn would alter of large molecules that play a role in controlling the internal processes, [49].

The efficacy of antitumor activity of ELF-EMF reported to be a suppressor of cell viability, was evaluated in Ehrlich ascites tumor [2] and [18]. Moreover, apoptosis characterized by nuclear condensation, membrane blabbing, cell shrinkage and a significant induction of Caspase-3 like protease activity

[32], loss of immunoreactive P53 [53], vascular occlusion by damaging of the vessels supplying the tumor-site [36], local pH changes and tissue ionization [17] were also observed.

The objective of this research was to study the major effects of ELF-EMF on Ehrlich ascites tumor cells and its side effects on female mice.

2. Material and Methods

Animals and Tumor Models

Female BALB/c mice, were implanted intraperitoneally with Ehrlich ascites tumor cells (EATC), obtained from the National Cancer Institute, Cairo University, Egypt. Seven days post-implantation (PI), the EATC were aspirated, counted and freshly used in our work. Seventy two female BALB/c mice (21 days old and having a weight of 25-30 gram) were obtained from the Laboratory Animal Housing, Faculty of Veterinary Medicine, Zagazig University. They were equally divided into 4 groups; groups 1 and 2 were kept as control groups, while gropus 3 and 4 have been used for IP with EATC. Groups 2 & 4 were exposed to 50 Hz EMF for 40 days immediately after implantation as shown in Table 1.

Table (1): Animal groups, numbers, treatment and day of sacrifice.

Animal groups	Numbers	Type of treatment		Day of sacrifice	
		2×10^6 EATC/mouse	50 Hz EMF	20 days	40 days
1	18	_	-	9	9
2	18	-	Exposed	9	9
3	18	I/P implanted	-	6+12*	-
4	18	I/P implanted	Exposed	7+2*	8+1*

*Died

The exposure apparatus

A magnetic field generator was designed and constructed; A solenoid consisted of coil 320 turns from electrically insulated 2mm thickness cupper wire around a cupper cylinder of 2mm thick, 40 cm diameter and 40 cm length. The cylinder wall was earthed to eliminate electric field component effects. The magnetic field generator should be temperature controlled during the exposure period by using water around the coil as shown in Fig 1. The temperature inside the exposing system was measured during the run of the experiment and there was no measurable difference in temperature between the room and the exposing system. The ends of the coil were connected to change the voltage fed from mains (220 V pp and 50Hz). The groups 2 and 4 were kept in special plastic cages that permit normal ventilation. The mouse cage was fixed on supports inside the middle of the coil as shown in Fig 1 to get homogenous and higher magnetic field strength which is 20 Gauss in our generator. Animals of groups 1and 3 were housed in a similar cage and conditions to the exposing system but without the magnetic field. All the animals received the same feeding diet, lighting, ventilation, and periodical cleaning along the run of the experiment.

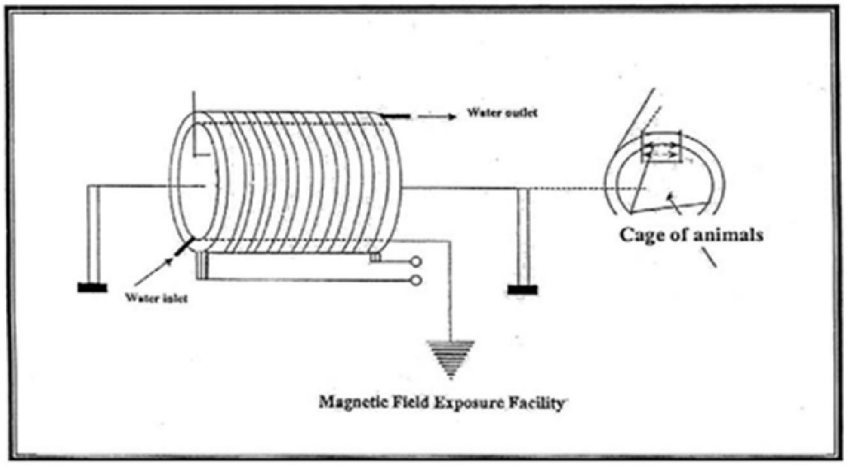

Fig.(1) Magnetic field generator

Clinic pathological Examinations

After anesthetization two blood samples were obtained from the retro-orbital venous plexus of mice in day 20 and day 40 from the beginning of exposure.

The first sample was collected in anticoagulant containing tubes (0.2 % EDTA for erythrogram and leucogram and 1% ammonium oxalate for platelet count) [15]. The second blood sample was collected in clean and dry centrifuge tubes. Tests included total bilirubin [33], α-fetoprotein [1], gamma glutamyl transferase (GGT) [47] alkaline-phosphatase (AP), [4], aspartate aminotransferase (AST) and alanine aminotransferase (ALT),[39], total proteins [38] blood urea nitrogen (BUN),[37], creatinine,[44], uric acid [23], calcium, [41], inorganic phosphorus [19], sodium and potassium, [22]. The statistical analysis of the biological data was performed using the methods Harnet (1994) to asses to significance of the differences between mean of control and the treated grains using t-test.

Examination Of Ehrlich Ascites Fluids

After sacrifice of mice, the peritoneal cavity was opened carefully and all ascites fluids were aspirated and examined for physical (volume, pH and specific gravity), chemical (total and crude proteins) and microscopic (tumor-cell count and viability) changes. The tumor-cell count was done using a Neubauer hemocytometer, erythrocyte pipette and Try pan blue stain [7].

Extraction and Classification of the Crude Protein from the Tumor Cells

The classification of the total protein of the tumor cells extracted from groups 3 and 4 was carried out by discontinuous electrophoresis [27]. The molecular weights of the protein bands were estimated by SDS polyacrylamide gel electrophoresis according to the methods of **weber** [56]. Seven standard protein markers of known molecular weights were used as standard protein.

3. Results

Clinicopathological Investigation

Analysis of the ascites fluid from mice implanted I/P with EATC cells) (Table 2, group3) showed an increase in the volume, specific gravity, total protein content, percentage (95.6%) of viable neoplastic cells and a decrease in pH. Meanwhile, the treated mice (group 4) showed 79% of dead and degenerated neoplastic cells stained blue with Trypan blue stain.

Table 3 illustrates significant increases in the erythrocyte count, hemoglobin content and packed cell volume, and insignificant changes in the mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration in the untreated EATC-bearing mice (group 3). Other groups showed insignificant increases in comparison with the control groups 1 and 2. The leucogram showed a significant increase in the total leukocyte and neutrophil counts in group 3 (as compared with control values for groups 1 and 2). A significant monocytosis and insignificant change in the other leukocytic parameters was measured in group 4. Moreover, a significant monocytosis was noticed in the exposed control group 2. Platelet count showed insignificant change in all groups.

Table 4 shows a significant increase in the serum total bilirubin, α-fetoprotein, AST, ALT, BUN, creatinine, uric acid, phosphorus, sodium and Na/K ratio a significant decrease in the serum total proteins, calcium and potassium with no change in GGT and AP levels in group 3.

Biophysical Investigation

Fig. 2 shows the disc electrophoretic pattern of the total protein content of the tumor cells extracted from groups 3 and 4 (20 and 40days). It is seen that the number of bands decreased from 18 for the unexposed mice (group 3) to 13 of the exposed ones (group 4) and also the amount of protein in each band decreased as it is shown in table (5).

Also Table 5 explains that there are some changes in the molecular weight of the bands of group 3 in comparison with group 4. These results explain that the molecular structure of the total protein content changeddue to the exposure process. These results indicate that exposure of the animals to the magnetic field caused a decrease and change in molecular structure of the protein content of the implanted tumor cells which consequently may alter their division and hence inhibit their growth [13].

Table (2): Physical, chemical and microscopic characteristics of Ehrlich ascites fluids.

Variable		(ml)	PH	Sp. Gr.	Total protein (g/dl)	Neoplastic cells		
						Viable (%)	Dead (%)	Viable / dead ratio
Group 3(34)	20 days	14.8 a ±0.82	6.5 b ±0.02	1.027 a ± 0.002	4.7 a ±0.52	95.6 a ±3.12	4.4 b ±0.41	21.73 a ±1.51
Group 4(35)	20 days	4.5 b ±0.22	7.5 a ±0.04	1.015 b ±0.001	2.0 b ±0.31	21 b ±1.05	79 a ±2.01	0.27 b ±0.02
	40 days	4.6 b ±0.16	7.5 a ±0.03	1.015 b ± 0.001	2.01b ±0.4	22 b ± 1.03	78 a ±2.02	0.28 b ±0.01

Table (3) The hematological parameters (Mean ± S.E.) in the control mice (48) and those implanted I/P with EATC, with or without EMF exposure. (49}

Variable		RBC count x10^6/µl	Hb g/dl	PCV %	MCV Fl	MCH Pg	MCHC %	TLC X10^3/µl	Absolute differential leukocytic count (xIO^3/µI)				Platelets count (x10^3/µl)
									Neutrophil	Eos inophil	Lymphocyte	Monocyte	
Group (1)	20 days	6.3" ±0.12	12.0 ^{b} ±0.6	35.0 ^{b} ±3.1	55.55 ^{a} ±6.5	19.05 ^{a} ±3.0	34.28 ^{a} ±5.73	5.53 ^{c} ±0.88	2.95 ^{c} ±0.16	0.21^a ±0.01	1.98 ^{b} ±0.13	0.39 ^{c} ±0.01	450.00 ^{a} ± 170.4
	40 days	6.32 ^{b} ±0.12	12.2 ^{b} ±0.6	35.0 ^{b} ±3.1	55.55 ^{a} ±6.5	19.05 ^{a} ±3.0	34.28 ^{a} ±5.73	5.52^C ±0.88	2.94 ^{c} ±0.16	0.21 ^{b} ±0.01	1.98 ^{b} ±0.13	0.38 ^{c} ±0.01	450.00^a ± 170.4
Group (2)	20 days	6.5 ^{b} ±0.22	12.2 ^{b} ±0.5	36 ^{b} ±4.5	55.38 ^{a} ±8.70	18.46 ^{a} ±1.9	33.33 ^{a} ±31.2	5.69^C ±1.4	3.00 ^{c} ±0.25	0.20 ^{a} ±0.01	2.00 ^{b} ±0.2	0.49 ^{b} ±0.02	450.90 ^{a} ±162
	40 days	6.52 ^{b} ±0.22	12.4 ^{b} ±0.5	36 ^{b} ±4.5	55.21 ^{a} ±8.70	19.02 ^{a} ±1.9	34.44 ^{a} ±11.2	5.76^c ±0.55	3.01 ^{c} ±0.30	0.21^a ±0.02	2.01 ^{b} ±0.05	0.53 ^{b} ±0.01	451.00^a ±156
Group (3)	20 days	7,5 ^{a} ±0.41	14.0 ^{a} ±1.66	41.5^a ±4.2	55.33 ^{a} ±7.5	18.67 ^{a} ±3.1	33.73 ^{a} ±4.26	7.50 ^{b} ±1.38	4.41^b ±0.3	0.22 ^{a} ±0.02	1.99 ^{b} ±0.2	0.38 ^{c} ±0.01	451.66^a ± 168.4
Group (4)	20days	6.99^{ab} ±0.31	13.4^{ab} ±0.85	37.5 ^{ab} ±3.9	53.65 ^{a} ±9.2	19.17 ^{a} ±2.5	35.73 ^{a} ±6.2	5.94 ^{c} ±0.9	2.99^c ±0.17	0.20^a ±0.01	1.95 ^{b} ±0.1	0.80 ^{a} ±0.03	453.40^a ± 153.0
	40days	*6.6*^{b} ±0.5	13.0 ^{ab} ±0.55	37.0 ^{ab} ±5.2	55.98 ^{a} ±8.5	19.67 ^{a} ±3.4	35.14 ^{a} ±5.0	5.98 ^{c} ±0.57	2.95 ^{c} ±0.2	0.20 ^{a} ±0.02	1.95 ^{b} ±0.17	0.88 ^{a} ±0.1	452.00 ^{a} ±161
F. test		*			N.S.	N.S.	N.S.		**	N.S.	*	*	N.S.
L.S.D.		0.435	0.751	1.663	-	-	-	0.562	0.601	-	0.543	0.281	-

Means within the same column having different alphabetical letters are significantly different*, Significant at probability 0.05. ** Highly
Significant at probability 0.01., N.S.: Non significant , L.S.D.: Least significant difference, EMF: Electromagnetic field.

Table (4): The liver and kidney function parameters (Mean ± S.E.) in the control mice and those implanted I/P with EATC, with or without EMF exposure.

Variable		Total bilirubin mg/d l	a-fetoprotein mg/d	GGT U/I	AP U/I	AST U/I	ALT U/I	Total proteins g/dl	BUN mg/dl	Creatinine mg/dl	Uric acid mg/dl	Calcium mg/dl	Phosphorus mg/dl	Sodium mEq/1	Potassium mEq/1	Na/K ratio
Group (1)	20 days	1.5 b ±0.16	2.3 b ±0.17	2.82a ±0.56	16.9a±2.2	66.97cd±4.85	24.5e ±2.8	7.84' 1=1.2	46.4 b±7.9	0.5 d ±0.04	3.3 c±1.2	10.4 a±2.1	7.0 £ ±1.8	152.5 c±12.7	7.3 a ±0.5	20.85d±3.2
	40 days	1.52b ±0.16	2.31b ±0.17	2.8a ±0.56	16.93a±2.2	66.96cd ±4.85	24.51c ±2.8	7.84a 1=1.2	46.6"±7.9	0.51" ±0.04	3.4 c ±1.2	10.5 a ±2.1	7.0 £ ±1.8	152.5 c±12.7	7.3 a ±0.5	20.85d±3.2
Group (2)	20 days	1.6b±0.18	2.24b ±0.62	2.9a ±0.47	17.2a ±1.89	70.0cd ±8.6	24.45C±3.7	7.86 a ±1.13	46.6 b±5.8	0.51d ±0.03	3.4 c ±1.1	10.2 a ±1.8	7.2 c ±1.5	151.6 e ±9.5	7.4 a ±0.42	20.49d ±4.1
	40 days	1.55 b ±0.14	2.26 b ±0.5	2.86* ±0.6	17.5a ±2.5	68.5£d ±6.3	24.5c ±2.11	7.85a ±1-04	47 » ±4.5	0.51d ±0.02	3.43 c ±1.2	10.15 a ±1.19	7.14 c ±1.44	151.33° ±10.2	7.5" ±0.3	20.69d±3.7
Group (3)	20 days	2.86a ±1.2	2.51a ±0.46	3.7ab ±0.74	18.9ab ±2.6	90.56b±12;5	60.78a ±8.44	5.35 b ±0.7	60.55a ±9.5	1.4 a ±0.2	5.88 a ±1.20	6.04 b ±0.5	11.5 a±A.66	178.6 2 13.4	4.5 c ±1.6	39.69* ±6.5
Group (4)	20 days	1.71" ±0.65	2.31 b ±0.36	2.82s ±0.56	17.33a ±2.5	68.12cd ±9.7	25.4c ±3.2	7.0acd ±0.61	49.0 b±7.4	0.6 dc ±0.1	3.5 bc ±0.97	9.59 B ±1.8	7.5 c ±0.9	166.0 b ± 11.0	6.42 b ±1.0.8	25.86C ±4.9
	40 days	1.72" ±0.52	2.34 b ±0.30	2.91a ±0.66	17.5a ±3.6	69.0cd 6.5	25.6e ±4.0	7.04acd ±0.46	4S.5b ±6.6	0.54 d ±0.05	3.5 lbc ±0.7	10.05 a ±0.81	7.8 c ±1.02	166.09b ±10.77	6.0 b ±0.55	27.68b±5.77
F. test		**	**	N.S.	N.S.	**	***	**	***	**	**	***	**	***	**	**
L.S.D.		0.511	0.876	-	-	4.60	7.431	1.950	10.70	0.326	0.971	2.50	0.973	6.750	0.745	5.782

Means within the same column having different alphabetical letters are significantly different.
** Highly significant at probability 0.01, *** Very highly significant at probability 0.001.
N.S.: Non significant, L.S.D: Least significant difference, EMF: Electromagnetic field.

Table (5): The change in the molecular weight (Mol. W.) and the percentage of protein in each band for groups 3 and 4

Number of bands	Uncxposcd cells (group 3)		Exposed cells to 20 days (group 4)		Exposed cells to 40 days group 4)	
	Mol. \V.	Protein %	Mol. W.	Protein %	Mol. W.	Protein %
1	162.29	0.04				
2	145.15	0.16				
3			132.68	0.09	131.7	0.09
4	127.23	0.09				
5	89.82	0.18	89.87	0.27	89.88	0.23
6	72.77	0.43	72.88	0.32	72.77	0.32
7	60.81	5.65	60.95	2.92	60.81	1.90
8	47.55	17.61	48.41	11.01	48.41	10.11
9	35.13	4.31				
10	33.14	5,44	33.48	3.01	33.48	0.06
11	32.42	1.71				
12	31.77	3.22	32.05	1.84	32.05	0.03
13	30.78	2.71	31.12	1.21	31.12	0.03
14	27.87	0.71	27.87	0.52	27.87	0.01
15	24.64	0.25				
16			22.05	6.61	22.51	0.08
17	20.43	4.28				
18	16.71	2.89	16.71	2.85	16.71	0.04
19			13.88	2.21	13.88	0.63
20	1136	1.08				
21	9.29	3.49	9.95	1.89	9.95	0.02
Sum		54.25		34.75		15.53

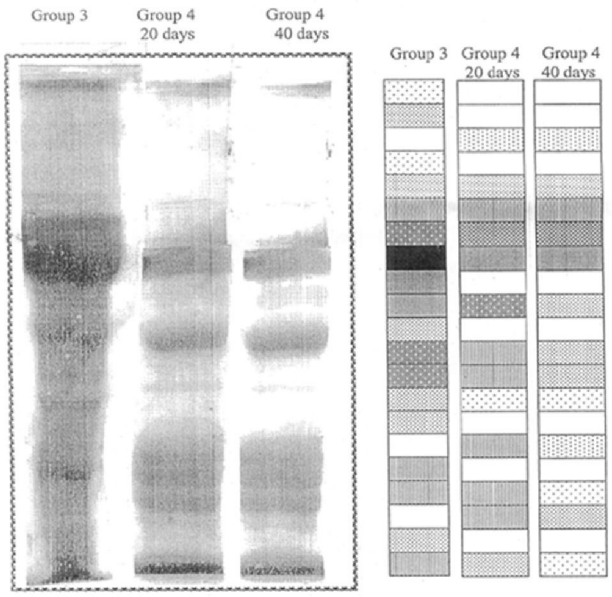

Fig.(2) The disc electrophoretic pattern of the crude protein of all groups.

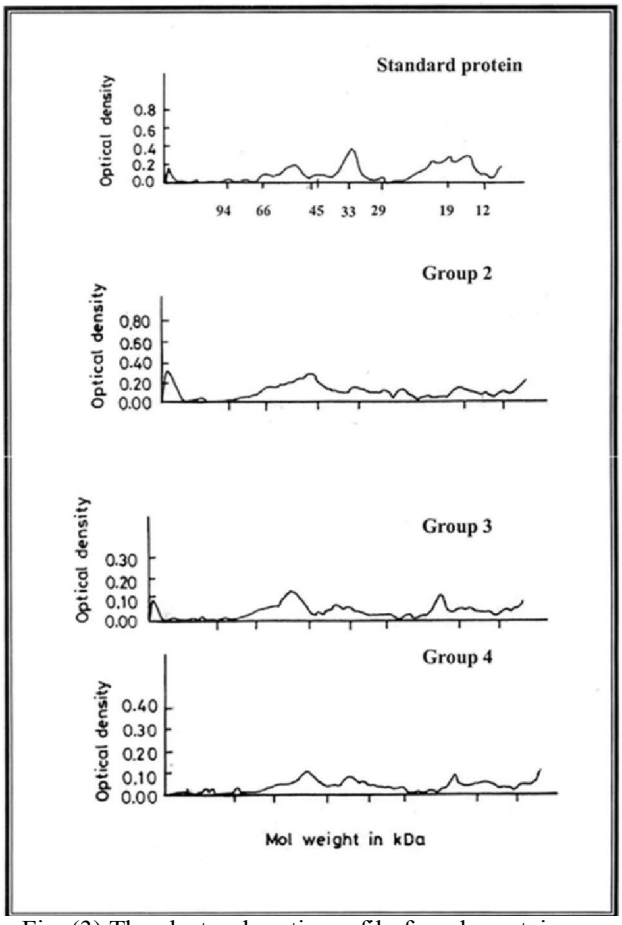

Fig. (3) The electrophoretic profil of crude protein extracted from group (2, 3 &4).

4. Discussion

The results presented in this work suggest that the starting time of exposure, which started directly after the implantation and the exposure rate may play an important role in controlling the tumor growth. The present investigation revealed that most group 3 mice (I/P implanted with $2x10^6$ EATC) died within 20 days PI, while those of group 4 mice (I/P implanted with $2xl0^6$ EATC and exposed to ELF-EMF) survived to the day of sacrifice (20 or 40 days). These mortalities in group 3 could be attributed to extremely rapid tumor growth and abdominal enlargement by ascites fluid, which mechanically interfered with the respiration and circulation. Meanwhile, the increased survival period (life span) among group 4 mice may be due to the cytotoxic action of EMF on the neoplastic cells through of apoptosis and inhibition of cell divisions [24, 35]. The obtained results agree with many authors [18, 36, 52].

The examination of Ehrlich ascites fluids (Table-2) revealed an increase tumor cell count, volume, total protein concentration and specific gravity in the mice of group (3) giving them the characteristic features of exudates, which are evidence of an inflammatory process, beside the anaplastic changes observed in the tumor cell-cytoplasm and nuclei were also higher than observed in other groups [28,54].The increase in the Ehrlich tumor cells may be due to a high mitoses and fewer cells dying. The high mitosis rate could be explained by the high Na/K ratio observed in this work, while fewer cells dying could be attributed to the decrease rate of the natural death mechanisms that occur in the tumor (e.g. apoptosis), as reported by **Cabrales** [7]. The accumulation of such fluid in the peritoneal cavity was either due to: (i) a reduced lymphatic recovery system, which is associated with the obstruction of the draining lymphatic by tumor cells (ii) angiogenesis, was detected in ascites tumor-bearing peritoneal walls (iii) micro vessel's hyper permeability of the peritoneal cavity [16]. Decrease in the total ascites volume was observed in EMF treated mice (group 4) that was followed by a numerical decrease in the total number of Ehrlich tumor cells. These results may indicate that the EMF-anti-inflammatory effects were responsible for the decrease in the total volume of ascites fluid, and in the total proteins and specific gravity measured in these fluids (group 4) as compared with non-treated controls moreover EMF may produce membrane Na-K ATPase inhibition. This inhibition would contribute to increased intracellular calcium and decreased magnesium, which can cause mitochondrial dysfunction and apoptosis [55]. These findings are confirmed by our pathological results, which show apoptosis through numerous eosinophilic shrunken bodies with or without condensed and fragmented nuclei in smears of group 4 EATCs. Concerning the

hemato-biochemical changes in the present work, the results are tabulated in Tables 3 & 4. There were insignificant changes in the studied parameters in the control mice exposed to EMF (group 2) when compared with the unexposed one (group 1) with exception of significant monocytosis in group (2). This finding agrees with **Dorofteiu** [10] who showed increased monocytosis in EMF treated vs. nul magnetic field exposed rats.

Group 3 mice implanted I/P with EATC showed a significant increase in erythrocyte count, Hb content and PCV. These results may be attributed to dehydration as a result of increased body fluids withdrawal for the higher mitoses rate of tumor cells, development of ascites in these animals, in addition to the pressure of an enlarged abdomen on the internal organs, and blood vessels (causing congestion), resulting in increased hydrostatic pressure inside the blood vessels followed by edema (group 3). Similar comments are reported by other investigators [25].

The leucogram in the mice showed a significant increase in the total leukocyte and neutrophil counts with no significant change in eosinophil, lymphocyte and monocyte counts, as well as platelet count, comparatively with the control (group 1).The acute inflammatory response or stress could explain the leukocytosis with neutrophilia. Regarding liver and kidney functions evaluation in mice of group "3" (Table 4), the serum levels of bilirubin, α-fetoprotein, AST, ALT, BUN, creatinine, uric acid, inorganic phosphorus and sodium were significantly increased, while the serum total proteins, calcium and potassium were significantly decreased. Such results were confirmed with the presence of hepatic and renal damages as a result of cancer cells invasion [21].

The available reported data of the biological effects of magnetic field are contradictory. Some reported that magnetic field have serious effects like promoting or co-promoting tumors [31], reducing melatonin production [40] and altering the membrane permeability of cells, especially RBCS [29] and some reported that early treatment of the tumor cells by extremely low frequency electromagnetic field (ELF-EMF) gave better result than delayed treatment [14]. This serious effect of the magnetic field on the normal cells can be used for getting rid of the tumor cells as an alternative easier treatment for the ionizing radiation used in radiotherapy. To get better understanding of the interaction mechanism of magnetic fields with biological systems, an understanding of the bioelectrical signals resulting from biological system during metabolic activity is required.

It is well known that biological cells carry their metabolic functions through ionic currents which result in bioelectric signals. The form frequency and amplitudes of these signals depend on the mode of the metabolic function. The influence of an external alternating magnetic field on these moving ions will cause either enhancement or inhibition of a physiological phenomenon depending on the mode of intubation. When the applied field frequency is at resonance with a specific bioelectric impulse, generated during a physiological process maximum interference occur (instructive or destructive) depending on the wave form of the applied field [11, 14]. [The changes in the ionic currents of the biological cells through their metabolic function resulting from exposure to external alternating magnetic fields (EMF) can involve electrochemical processes in the cells that influence cellular functions. Moreover, these magnetic fields and currents circulating into the extracellular medium can alter ion binding to membrane macromolecules, influence ion transport across the membrane and modify ligand-receptor interactions at the cell membrane surface. These changes in membrane properties will lead to changes in the ion transport mechanism and hence affect cellular growth state [13]. The mechanism of interaction of the demonstrated electromagnetic field with the tumor cells at this frequency may be the resonance destructive interference with the electric impulses generated from ionic motions in tumor cells division, resulting in tumor growth inhibition and death.

The decrease in the protein content and the change in its molecular structure following exposing the tumor cells to the demonstrated magnetic field may be due unclear formulation [20]. Treatment of tumor cells with low frequency electromagnetic field is promising. It has the advantage of minimizing the side effects of chemotherapy. However, there is still much work to be done to render this technique clinically applicable. The procedure should include investigating of other types of tumor organs, tumor stages and treatment period.

Conclusion

The hazard effect of the magnetic field on the tumor cells can be used for easier treatment than ionizing radiation used in radiotherapy. The results of protein electrophoresis revealed not only a decrease in the protein content of the Ehrlich tumor, but also considerable changes in its molecular structure as a result of exposing to 20 or 40 days of EMF. Such a decrease was found to be proportional to the exposure periods. Early treatment of the tumor cells by extremely low frequency electromagnetic field gave better results.

This phenomenon opens a completely new avenue for developing a safe treatment to control some cancer cells.

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