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Functionality of natural killer cells from end-stage cancer patients exposed to coherent electromagnetic fields

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The main objective of our study is to investigate whether an enhancement of the immune system in end-stage cancer patients is achieved by exposure to coherent electromagnetic fields. For this reason, 15 end-stage cancer patients were exposed at low intensity, coherent electromagnetic fields at radiofrequencies ranging from 600 kHz – 729 Hz, for 8 h/day, 6 days/week for 4 weeks. NKs number and cytotoxicity of NK T-lymphocytes versus K562 cancer cell line were estimated by flow cytometry, before and after exposure. Data showed that the exposure of the end-stage cancer patients to the coherent electromagnetic fields resulted in a significant increase of the number and the cytotoxicity of the NK T-lymphocytes against cancer cells, in all patients. Exposure to coherent EMFs at radiofrequencies increases the number and cytotoxicity of NK T-lymphocytes, which may contribute to the improvement of cancer patients' status.

Keywords Natural killer cells, Flow cytometry, Coherent electromagnetic fields, Electromagnetic resonance

INTRODUCTION

Natural killer (NK) cells play an important role in integrating immune processes, constituting a first line of defence against various infections and malignancies (Reynolds and Ortaldo, 1987; Trinchieri, 1987; Cerwenka and Lanier, 2001). One possible mechanism may be that NK cells unlike cytotoxic T cells, do not recognize a specific antigen before their action and selectively kill target cells bearing low levels of Major Histocompatibility Complex (MHC) class I molecules on their surface (a non MHC-I restricted action). Activated NK cells produce IFN-γ which increases VCAM-1 (Vascular cell adhesion molecule-1) expression facilitating the binding of NK cells to their target cells (Cerwenka and Lanier, 2001; Kim et al., 2005). In case of malfunction of the NK cells, an essential imbalance in immune – tumor interactions occurs and neoplastic cells evade immune surveillance (De Pillis et al., 2005).

Electromagnetic fields (EMFs) have been widely studied for their effects on biological species including humans (Foster and Repacholi, 2004). Such EMF at the

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radiofrequency level (RF) are usually found in earth environment, coming from cosmic radiation and- or emitted by communication systems and other technologies. Humans and other species are therefore well adapted to radiofrequencies and is well documented that these low EMF are harmless for animals and humans, since they are at radiation levels below accepted guidelines (Challis, 2005). There are, however, quite a few data on the effects of EMF on various kinds of malignant cells in experimental animals and in humans, some of them referring to the application of electromagnetic resonance field's principles at radiofrequencies (Suss, 1997; Islamov et al., 2002). The main concept expressed so far referring to the effects of EMF on malignancies are: their intensity, frequency, and duration of application. Studies on the EMF anticancer effects in vitro are several and their methodology is well documented (Tofani et al., 2002; Rossi et al., 2007; Kirson et al., 2007; Colbert et al., 2009). It has been also shown that the cytostatic effects of the EMF on cancer cells are not related to their thermal effects, being temperature-independent (Han et al., 1998).

EMF at 1.95 MHz induced apoptosis in human epidermoid cancer cells (Garaglia et al., 2005). Low-intensity, intermediate frequency (100–300 KHz) alternating EMF induces growth inhibition of malignant tumors in mice (Kirson et al., 2004). Beneficial effects of RFs in cancer patients suffering from brain glioblastoma have been attributed to the hindering and the formation of the mitotic spindle of cancer cells. This is due to the effect of the electric field on the large dipole moments of the tubulin dimmers of the mitotic spindle (Kirson et al., 2007). We have also recently shown that coherent EMF at RF (of 10 kHz–120 kHz) exerts potent antiproliferating and apoptotic effects on malignant sarcoma cell lines, as well as on sarcoma-bearing Wistar rats (Karkabounas et al., 2006; Avdikos et al., 2007).

There is, however, no evidence whether coherent EMFs at RFs enhance the immune system of cancer patients. For this reason, the effects of exposure to coherent static EMFs at RFs on the number and the cytotoxicity of NK T-lymphocytes, in end-stage cancer patients were investigated.

MATERIALS AND METHODS

Patients

Fifteen end-stage cancer patients (5 males and 10 females), aged from 28–79 years, participated voluntarily in the study. All patients were fully informed for the protocol of the study and signed consent of participation. The protocol of the study was approved by the Research Committee of the University of Ioannina and by the National Ethical Committee (15217/3-3-2006). The procedures followed were also in accordance with the ethical standards on human experimentation of the Helsinki Declaration of 1975, as revised in 1983.

Patients had completed their chemotherapy, radiation, and/or adjuvant antioxidant treatment (ascorbic acid 200 mg/kg body wt/day, β-carotene 1.5 mg/kg body wt/day, α-tocopherol 15 mg/kg body wt/day and vanadium as supplement 0.1 mg/kg body wt/day in the form of vanadium-cysteine and/or vanadium-putrescine) (Kallistratos et al., 1994; Liasko et al., 1998) at least 4 weeks before participation to the study, according to protocols for patient eligibility requirements indicating that chemotherapy or irradiation has to be stopped at least 4 weeks before exposure of cancer patients to EMFs (Ronchetto et al., 2004). There is, however, evidence that antineoplastic chemotherapy can be safely combined with magnetic fields (Salvatore et al., 2003). Patients received no medications during the study. Type of malignancy and stage of cancer were confirmed by histology and CT or MRI. Blood biochemistry (urea, creatinine, glucose, SGOT/SGPT, AlP, γGT, LDH, AFP, and CEA), haematological analysis (white, red blood cells, Hb, ESR and platelets),

and tumor markers (α-FP, CEA, Ca19-9) were also measured. Patients were required to have adequate bone marrow, renal, and liver function (Ronchetto et al., 2004). NK cells were also counted and NK cells cytotoxic activity versus K562 tumor cells was measured before and after the end of the study. A complete history was received and physical examination of each patient was performed before enrollment in the study. No female patient was pregnant. The basic clinical characteristics and treatment history of the patients enrolled in the study are shown in Table 1. As control group, we considered NKs number and function of the volunteers before treatment with EMFs. Furthermore, as control were used publications concerning NKs function in cancer patients treated with chemotherapy or radiation.

Devices used and plan of exposure to EMF

EMF measurements and static EMF exposure of patients were performed using the Multi Channel Dynamic Exciter 100 V1 (MCDE) and described in detail elsewhere (Karkabounas et al., 2006; Avdikos et al., 2007). The MCDE has been certified by the Greek Committee of Atomic Energy (EEAE) for its safe use in humans and animals (ΕΕΑΕ ΜΙΑΕΕΠ2, 15/11/2000) (Karabetsos, 2000). The measurement part of this device (Figure 1A) emits through electrodes the resonant radiofrequencies of healthy tissues, cells, and organs of humans or animals by a database and their response is recorded. The more the response is deviating from the emitted frequency (in Hz) the more significant is the impairment of the organ and other targets (cells or tissues) (Popp, 2003; Takeda et al., 2004). The database (Fig. 1B) of the measurement part of the device contains the resonant frequencies of various human tissues and organs obtained mainly by measurements of Magnetic Resonance Imaging devices which recorded the resonant frequencies of each organ and transform them to an image. These are the normal resonant frequencies of any physiological structure in the human body which deviates in pathological structures.

The apparatus provides a uniform whole body exposure of the patients to the EMF. Patients during treatment were comfortably sitting at room temperature in a Faraday Cage (Fig. 1C) to avoid interaction with external-environmental electromagnetic resonance, at a determined distance (approximately 1 m) from the dipole antenna of the device so that the resonant radiofrequencies (RF) emitted, to be absorbed according to different conductivities of the human tissues of each patient (Allen et al., 2003). All patients were exposed to EMF at RF (Table 2) for 8 h/day, 6 days/week for 4 weeks. The frequencies used in this study conducted by a sophisticated program via a PC based on an algorithm and aimed to "force" any deviating system or organ in the body to resonate to its normal frequencies. The low frequencies used for exposure of the patients (from 600 kHz–729 kHz) are considered in relation to their intensity harmless for human and animals.

Equipment and reagents for flow cytometry

The necessary apparatus included the following: pipettes with tips, water bath, CO_2 incubator at 37°C, digital thermometer, vortex mixer, hematocytometer chamber, cover slip or electronic counter, centrifuge with swinging buckets and 12x75 mm tube carriers (Beckton-Dickinson, USA), flow cytometer (argon–ion Laser) with 488 nm excitation wavelength (Beckton-Dickinson, USA), ice bath with cover, and disposable tubes of 15 and 50 ml.

The reagents included prestained and unstained K562 target cells (ATCC, USA), stored at −70°C, complete medium consisting of RPMI 1640 with addition of streptomycin (Gibko, USA), DNA staining solution (Sigma, USA), Isopaque-Ficoll solution (Sigma, USA), and sterile phosphate buffered saline (PBS, Gibko, USA).

TABLE 1 Cancer type, metastases, and previous treatment of the 15 cancer patients, enrolled in the study

Nr	Sex	Age	Type of Cancer	Metastases	Adjuvant treatment	Chemotherapy
1	F	38	Ductal Cancer of the breast	Liver, lungs, lymph nodes, brain	Antioxidants, V-cys, V-putr	Paclitaxol
2	F	52	Ductal Cancer of the breast	Liver, lungs, lymph nodes, brain	Antioxidants, V-cys, V-putr	Paclitaxol
3	F	66	Ductal Cancer of the breast	Liver, lungs	Antioxidants	None
4	F	75	Adenocarcinoma of the colon	Liver	Antioxidants	5-Fluoro-uracil
5	F	79	Non Hodgkin's lymphoma	Multiple organs (thoracic, abdominal and neck lymph nodes)	Antioxidants, V-cys, V-putr	None
6	F	28	Fibrosarcoma of quatrocipite muscle	Multiple lung metastases	V-cys, V-putr	None
7	M	36	Melanoma of the retina	Multiple brain metastases	Antioxidants, V-cys, V-putr	None
8	M	52	Adenocarcinoma of the lung	Multiple metastases in both lungs	Antioxidants, V-cys, V-putr,	Cis-platinum, taxol
9	M	68	Adenocarcinoma of the colon	Bones	Antioxidants, V-cys, V-putr	None
10	M	49	Non small cell carcinoma of lung	Bones	Antioxidants	Cis-platinum, taxol
11	M	55	Non Hodgkin's lymphoma	Thoracic, abdominal and neck lymph nodes	Antioxidants	None
12	F	52	Breast cancer, adenocarcinoma	Bones	None	Paclitaxol
13	F	70	Adenocarcinoma of the colon	None	Antioxidants, V-cys, V-putr	5-Fluoro-uracil
14	F	47	Adenocarcinoma of the ovary	Lungs	Antioxidants, V-cys, V-putr	Cis-platinum, taxol
15	F	54	Breast cancer, adenocarcinoma	Lungs	Antioxidants	Paclitaxol

F, female; M, male; V-cys, vanadium-cysteine; V-putr, vanadium-putrescine; None, no chemotherapy.

FIGURE 1. The Multi Channel Dynamic Exciter 100 V1 (MCDE). (A) Dipole antenna; (B) Pc's sophisticated program; (C) Faraday cage.

METHODOLOGY OF NK CYTOTOXICITY BY FLOW CYTOMETRY (FCA)

The basic principle of the quantification of the cytotoxic activity of NK cells with FCA is to discriminate between effector (NK cells) and target (cancer) cell populations. The cell line K562 (cryopreserved, obtained from American Type Culture Collection, Manassas, VA) is used as target cells prestained with green fluorescent membrane dye (Beckton-Dickinson, USA). The K562 cell line was derived from the blood of a patient with chronic myeloid leukemia in terminal blastic crisis, and represents the most sensitive target cell line for human NK cells (Kane et al., 1996). K562 cells lack MHC classes I and II antigens. After incubation of the effector and the target cells, a red fluorescent DNA dye (Sigma, USA) is added to label the target cells permeabilized by NK activity. This dye labels only cells with compromised plasma membranes. In this way, a clear separation between four cell populations can be obtained: live target cells, dead target cells, live effector cells, and dead effector cells. Thus, the actual ratio between effector and target cells (E:T) can be confirmed, but only events that appear to be positive after this analysis (dead and live targets cells) will have to be collected for the determination of the NK cytotoxic activity (Sorskaar et al., 1985; King and Radicchi-Mastroianni, 1996).

Methodology of estimation of the number of NK and NK T cells

In six falcon tubes 12 × 75 mm, 20 μl of CD16, 56 monoclonal antibodies (Becton-Dickinson) were placed, respectively. Then, 100 μl of whole blood was placed in EDTA/K3 tube and was set in concentration of 4,000 cells/μl up to 10,000 cells/μl

TABLE 2 The 491 radiofrequencies used for emission (in Hz)

600222	607020	613740	620515	627320	634652	641480	648615	657908	665378	673321	680230	688762	700050	709521	719012	726380
600444	607232	614052	620726	627541	634864	641701	649026	658121	665710	673632	680752	689073	700261	710032	719230	726601
600666	607544	614263	621028	627753	635075	642012	649448	658443	666022	673843	681064	689285	700573	710243	719442	726812
600881	607757	614475	621250	628065	635287	642224	650060	658774	666344	673956	681275	689496	700884	710455	719655	727024
601103	608080	614687	621462	628307	635510	642435	650483	659086	666556	674067	681587	689739	701105	710666	719867	727435
601314	608303	615108	621674	628520	635721	642646	650905	659620	666868	674380	681809	690050	701317	710878	720080	727548
601525	608514	615310	621886	628732	636033	642859	651228	659832	667180	674602	682022	690261	701530	711090	720301	727760
601736	608725	615521	622108	629044	636245	643070	651560	660054	667402	674813	682324	690472	701732	711302	720514	728071
602047	609036	615732	622420	629366	636457	643302	652072	660266	667614	675025	682756	691204	702043	711514	720725	728282
602250	609247	616043	622632	629679	636669	643513	652385	660478	667726	675237	683067	691416	702254	712026	721036	728604
602462	609460	616254	622843	629890	637000	643725	652708	660680	668038	675448	683280	691628	702566	713439	721247	728827
602674	609682	616465	623054	630102	637222	644036	653020	660902	668460	675660	683502	691840	702878	713658	721458	
602887	609903	616677	623267	630313	637434	644250	653333	661114	669071	675871	683714	692051	703091	713888	722070	
603110	610105	616889	623480	630525	637646	644582	653550	661325	669303	676082	684025	692673	703502	714072	722381	
603322	610317	617101	623692	630736	637857	644793	653763	661538	669615	676303	684237	693085	703715	714290	722594	
603534	610530	617312	623903	631047	638059	645105	654075	661750	669827	676514	684770	693411	704027	714514	722805	
603745	610742	617523	624115	631258	638280	645317	654306	662061	670040	676725	685081	693832	705039	714827	723016	
604056	610965	617734	624327	631692	638631	645530	654518	662273	670242	677036	685302	694044	705351	715040	723227	
604267	611177	618045	624539	631904	638726	645742	654830	662505	670454	677250	685514	694965	705562	715251	723440	
604480	611390	618257	624750	632115	639038	646053	655042	662717	670665	677461	685826	695177	705773	715764	723651	
604701	611601	618469	625061	632327	639250	646285	655354	663029	670877	677672	686038	695820	706084	716076	723852	
604912	611823	618691	625272	632538	639461	646497	655666	663241	671088	677883	686350	697532	706405	716388	724063	
605123	612035	618903	625485	632750	639673	646710	655979	663452	671310	678104	686561	697844	706616	716812	724274	
605336	612248	619014	625706	633061	639885	647021	656190	663673	671521	678626	686873	698146	706828	717023	724686	
605551	612460	619227	626017	633273	640097	647232	656402	663885	671733	678838	687084	698459	707040	717234	724907	
605763	612671	619440	626229	633485	640320	647456	656614	664097	672044	679050	687405	698780	707351	717745	725118	
606074	612882	619651	626442	633707	640532	647668	657030	664410	672275	679261	687616	699102	707863	718056	725430	
606285	613103	619862	626654	634018	640743	647880	657252	664612	672477	679473	687828	699333	708075	718368	725643	
606507	613315	620073	626875	634230	641055	648091	657584	664824	672688	679804	688039	699535	708587	718580	725855	
606718	613527	620304	627107	634441	641268	648303	657796	665036	672910	680016	688251	699738	709110	718801	726177	

in each tube. Then mixed and incubated in dark room for 15 min in room temperature. In each tube 2 ml of lytic reagent was placed (dilution of reagent with distilled water in a ratio 1:10). Then, mixing and incubation is followed in dark and normal conditions. After 5 min of centrifugation of the tubes in 1,800 rpm per minute, the supernatant was discarded and 500 μl PBS was added and measurement with the flow cytometer was taking place after mixing the contents of the tube.

Statistical analysis

Data are expressed as mean ± S.D. The statistical significance between data means was determined by using paired-sample t-test. All statistical procedures were performed using SPSS ver. 16.0 (SPSS Inc. Chicago, Illinois, USA).

RESULTS

The leucocytes, platelets, and red blood cells count as well as blood biochemistry and body weight of the patients remained stable (data not shown). No side effects were recorded in the patients exposed to the EMFs.

All patients treated by EMF manifested an increase in total number of NK cells ranging from 1.1% (patient Nr 3 in Table 3) up to 351% (patient Nr 6, in Table 3). NK cytotoxicity was significantly increased at ratio of 12.5:1 in all patients, as well as in 7 out of 15 patients (46.7%) at ratio of 25:1 and 10 out of 15 (66.7%) at ratio 50:1 (Table 3).

The number of NK cells and NKT lympocytes also increased significantly after exposure of patients to the coherent EMFs at radiofrequencies ($p < 0.001$; Table 3).

No significant difference between hematological, biochemical parameters tumor markers, NK cells cytotoxic activity versus K562 tumor cells (ratio 25:1 and 50:1), before and after EMF at RF exposure, was observed. In contrast, NK cell number and NK cells cytotoxic activity versus K562 tumor cells at ratio 12.5:1 was significantly increased after EMF at RF exposure ($p < 0.001$).

DISCUSSION

Exposure of end-stage cancer patients to EMF at RF for 4 weeks resulted into a significant increase of the number of the NKs and NK T-lymphocytes in the group of the patients with an increase of NKs cytotoxicity in half of them. It is significant that NK cells were cytotoxic at low ratio such as 12.5:1, since at higher ratios they are nevertheless cytotoxic. In this small concentration, the faster immunomodulation of NKs functionality was proved because the more cytotoxic the NKs are in this concentration the more active and motile they are to face dangerous invaders.

The methodology of exposure to EMF, applied in the present study, has been previously shown by us, to exert significant anticancer effects either on malignant cell lines or in tumor-bearing experimental animals (Kane et al., 1996; Karkabounas et al., 2006). We approached end-stage cancer patients holistically trying to regulate all systems and functions. This is in accordance to findings indicating that cell population can be approached holistically on an entity regulated by a fully coherent biophoton field (Popp, 2009). Furthermore, there is evidence that a rational electromagnetic treatment appears to be the induction of conditions for soliton existence for maintaining the coherence of the system (Brizhik et al., 2009).

Recent studies indicate that EMFs applied on human body, through needle-like electrodes which are posed on selected body sites, may increase the activity of NKs. This phenomenon is related to the regulation of the expression of certain genes,

TABLE 3 The number of NK, NK T cells and their cytotoxic activity in 15 end-stage cancer patients, before and after treatment with EMF at RF

No/Sex	Age	%NK	NKT cells before treatment	%NK	NKT cells after treatment	Variation % of total NK cells after treatment	Cytotoxicity % of NK cells before treatment			Cytotoxicity % of NK cells after treatment			Variation in Cytotoxicity % of NK cells after treatment		
							12.5:1	25:1	50:1	12.5:1	25:1	50:1	12.5:1	25:1	50:1
1/F	38	10.57	1.17	21.41	6.12	+134	26	48	89	32	28	72	↑	↓	↓
2/F	52	6.16	5.54	10.16	20.43	+161	3	89	84	43	59	72	↑	↓	↓
3/F	66	20.14	3.14	19.25	4.15	+1.1	5	15	27	25	38	46	↑	↑	↑
4/F	75	2.48	3.45	5.45	6.78	+97	15	35	45	18	42	48	↑	↑	↑
5/F	79	3.55	1.50	8.60	3.50	+100	2	15	28	5	25	32	↑	↑	↑
6/F	28	5.89	1.70	17.69	16.55	+351	16	43	38	32	39	79	↑	↓	↑
7/M	36	6.27	3.23	10.62	15.46	+174.5	24	49	90	32	39	79	↑	↓	↓
8/M	52	6.80	5.40	10.20	6.35	+36	25	46	68	35	52	72	↑	↑	↑
9/M	68	5.25	4.35	8.55	12.70	+121	18	45	70	28	32	85	↑	↓	↑
10/M	49	15.29	2.45	16.80	4.60	+4,3	22	48	55	31	45	72	↑	↓	↑
11/M	55	6.45	4.25	12.70	10.25	+124	12	32	45	25	57	73	↑	↑	↑
12/F	52	8.30	3.70	15.20	6.70	+119	15	36	49	20	38	55	↑	↑	↑
13/F	70	3.60	5.25	9.20	12.80	+122	7	19	39	25	32	48	↑	↑	↑
14/F	47	6.70	3.60	14.55	10.25	+170	12	42	72	32	38	67	↑	↓	↓
15/F	54	5.95	3.45	17.36	8.58	+173	14	35	79	23	32	71	↑	↓	↓
Mean	54.7	7.6	3.5	13.2	9.7		14.4	14.4	39.8	58.5	27.1	39.7			
S.D.	14.6	4.6	1.4	4.7	5.0		7.8	7.8	17.9	21.7	8.8	10.0			

F, female; M, male

which are reported to play an important role in NK cell activation (Kim et al., 2005). EMF's are known to increase Ca^{2+} influx in cells (Ronchetto et al., 2004; Nadareĭshvili, 2006), and it has also shown that the influx of Ca^{2+} activates NKs (Kallistratos et al., 1994).

Exposure to EMF at RF has been shown to increase antioxidant system in lymphocytes in patients with rheumatoid arthritis (Islamov et al., 2002) exerting probably a non specific protection of NK T-lymphocytes. This is in consistent with our experimental data showing that plant antioxidants, such as resveratrol, enhance significantly NK T-lymphocytes' cytotoxicity against cancer cells.

Beneficial effects of RFs in cancer patients suffering from brain glioblastoma have been attributed to the hindering and the formation of the mitotic spindle of cancer cells. This is due to the effect of the electric field on the large dipole moments of the tubulin dimmers of the mitotic spindle (Kirson et al., 2007). In the present study, all the patients had already completed the ordinary therapeutical anticancer and adjuvant treatments and during their exposure period at the EMFs (10 kHz – 120 kHz) they were drug free. Only occasionally, they used in small doses of analgesics (opioids such as Durogesic) and tranquilants (benzodiazepines such as lorazepam and bromazepam) as palliative treatment. All the patients' anticancer and adjuvant treatments were interrupted for at least 4 weeks before their exposure to the EMFs (Ronchetto et al., 2004).

As is well known, it is very difficult to estimate if the overall patients' improvement is a clear result of EMF action only. It is also possible that the observed improvement could be at least partly attributed to the previous action of the ordinary therapeutic schemes. Nevertheless, there is also the possibility of an interaction between chemotherapeutics and EMFs, as it is already known according to the literature (Rossi et al., 2007). Preliminary experiments in our laboratory show that very small concentrations of cytotoxic drugs can demonstrate a synergetic phenomenon with EMF action by increasing the rate of cancer cell death. Furthermore, it is important to emphasize that the observed patients' improvement started to reveal during the exposure period to EMF. Finally, the possibility of a placebo effect should not be underestimated.

No significant difference between hematological, biochemical parameters tumor markers, NK cells cytotoxic activity versus K562 tumor cells (ratio 25:1 and 50:1) before and after EMF at RF exposure was observed. In contrast, NK cell number and NK cells cytotoxic activity versus K562 tumor cells at ratio 12.5:1 was significantly different after EMF at RF exposure ($p < 0.001$). Thus, this result could be at least partly related to the patients' improvement.

Several studies have demonstrated improved survival rates after the transfer of activated killer cells into cancer patients. NK cell activities are consistently lower in people with a family history of cancer compared to individuals with a low familial incidence of cancer (Strayer et al., 1984). In different patients in follow up, a serial monitoring of NK cells activity and correction of their emerging abnormalities after administration of an oral NK cell activator, revealed increasing overall and disease-free survival rates as well as prevention of cancer occurrences in high risk groups (Ghoneum, 1998). Furthermore, there is also reported that NK activity is inversely related to the number of family members with cancer. An eleven year study of 2,196 women, revealed that women with a high NK cytotoxic activity (>51%) had approximately half the risk of cancer compared with those with a low NK cytotoxic activity (less than or equal to 34%) (Imai et al., 2000).

In conclusion, increase in number and cytotoxicity of NK cells which seems to be critical for the prolongation of the survival time and quality of life of end-stage cancer patients, and may contribute to the beneficial effects of EMF at RFs.

Declaration of interest
The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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