Biological effects and applications on transient electromagnetic fields*

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Abstract

The athermal bioeffects and applications caused by transient electromagnetic pulses were studied by using a broad transverse EM-Wave cell (BTEM CELL). The results and mechanism are very different from that of continuous wave. The applications include that foreign DNA into living cells, fusion of cells, insertion of proteins into cell membranes, imporving drug delivery and effectiveness in chemotherapy of cancers. The athermal mechanism of transient EM-fiels were preliminarily presented

1. Introduction of bioeffects on transient EM-Fields

The bioeffects of the transient fields on biological bodies are very different from that of continuous wave, which is a newborn subject in bioelectromagnetism. The thermal and athermal biological effects on interaction of continuous wave with biont were focused on during the past half century while the interaction of transient electromagnetic field to biological bodies was seldon concerned. The reasons are as follows.

For continuous wave, biological features in bionts are relative to frequency, average power density and interactive time of incident wave. When incident EM field is a transient narrow pulse, the average power density becomes meaningless and almost zero. The biological effects are only relative to its waveform, amplitude and duraton of pulses. Their dosage standards are much different.

The interaction of transient field with bionts is instable and nonlinear. The duration of transient induced current in bionts is much shorter than that of continuous wave. The experiment requires

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an ultra wide band – wdith measurement system. Because transient field possesses a very wide spectrum (the frequency component extends almost from direct current to giga hertz). continuous wave experimental system of single frequency cannot be used.

To determine the effects on the cell membrane potential produced by a transient pulse, we consider the ANSI C 95.1 1974 standard. The power density is limited to be $100 w/m^2$, and the time interval is set to be 6 min. According to this limitation, an impulsive EM field with a total energy density of $36\ 000 J/m^2$ is admissible.

We have found that the above mentioned standard does not consider the athermal bioeffects of transient field on cell membrane of a biont. The transmembrane potential produced by transient field would be two orders greater than that by continuous wave. Owing to the existence of athermal bioeffects, one cannot only calculate the thermal effects.

2. Some results

The experiments were conducted in the BTEM CELL, Which has been designed by us[1].

We put the samples at different position in the BTEM CELL. There were different intensities of field at different points. The experimental samples were radiated for 1, 1.5, 2 and 3 respectively (table 1, figure 1)

Table 1 The effccts of transient EM – pulses on body's lymph cell(‰)

Time of radiation/h	Number of nucleus	Ratio of mini cell	t	Ratio of mini nucleus	t	Ratio of broken nucleus	t	Ratio of dyskaryosis	t
0	3 000	0.33		0.33		0.00		2.67	
1.0	3 000	0.33	0	1.33	0.776	0.67	0.819	23.3a)	4.075
1.5	3 000	0.33	0.581	2.33	1.222	2.00	1.415	24.7a)	4.24
2.0	3 000	3.00	1.464	4.33	1.855	1.67	1.293	35.0a)	5.318
3.0	3 000	1.33	0.776	3.67	1.672	2.33	1.527	39.7a)	5.75

a) $p < 0.01$. Noticeable symbol. t – test.

The ability of forming rosette of T – lymph cells was decreased very much. The longer the radiation time, the less the rosette, indicating that the immunity ability of cells had been destroyed (table 2 figure 2)

Table 2 Percentage of the E – rosette

	Normal	1.0h	1.5h	2.0h	3.0h
Total number	135	135	135	135	135
Number of E – rosette	97	73	50	30	18
Percentage(%)	72	54	37	22	13
t		3.029	5.714	8.716	9.27
p		<0.01	<0.01	<0.01	<0.01

In the table 1 and 2, the parameters of transient field are as follows; Gaussian type, rising time of pulse 1.2ns, duration time 2.4ns, amplitude 100v.

Table 3 Percentage of the E－rosette(%)

Grops	Conditions			Time	percntage	deereastd ratio	t	p
	Amplitude (V)	Duration (ns)	repeat frequency (KHZ)	(h)	%	%		
I	50	10	100	0	36.3	－	－	－
				1	24.8	31.7	5.6	<0.001
				3	23.3	35.8	6.4	<0.001
Ⅱ	50	10	1	0	36.3	－	－	－
				1	17.0	53.2	9.8	<0.001
				3	11.8	67.5	12.8	<0.001
Ⅲ	50	10	0.1	0	28.6	－	－	－
				1	14.8	48.3	7.5	<0.001
				2	21.2	25.9	3.3	<0.001
				3	27.5	3.8	0.5	>0.05
Ⅳ	50	50	1	0	27.1	－	－	－
				1	8.4	69.0	10.9	<0.001
				2	15.7	42.1	6.2	<0.001
				3	16.2	40.2	5.9	<0.001
Ⅴ	50	100	1	0	22.7	－	－	－
				0.5	22.1	2.6	0.3	>0.05
				1	14.8	34.8	4.5	<0.001
				2	18.9	16.7	2.1	<0.05
				3	19.0	16.3	2.0	<0.05

In the table 3. We used some different amplitudes, durations and repeat frequences of rectengular pulses. The values of most P are less than 0.001, It indicats that the affact of transient EM pulse to form E－rosette is much notieable.

3. The analysis of primary mechanism.

The interaction mechanism of transient EM field to biological cells, especially creation of athermal biological effect is a very diffecult. But We think that formation of electroporation in cell membrene can explain this process.[2] The present view that electroporation is a rapid process of structural rearrengemat within the cell membrane. Under radiation of transient EM field, many pores will be formed on lipid bilayer membrane, resulting in rapid changes in membrane. The electrostatic conductance of lipid bilayer membrane is due to very small pores spontaneously formed and destroyed. Application of transient EM field at proper intensity provides energy for enlarging these natural pores and may result in formation of electroporation. On the basis of free volume fluctuation and aqueous protrusion (dimple), hydrophobic pores were formed. And then hydrophilic pores of formation, which are called as “Primary pores”, the ions and molecules can pass through them, at last, composite pores were formed, some charged macromolecules can insered into the hydrophilic pores. The stochastic creation of microscopic pores is due to contribution from both “KT energy” and electromagnetic energy. The former is stochastic, associated with thermal fluctuation. The latter is deterministic, associated with the decreased barrier within pores of membrane.

After our calculation, some ions pass through a pore within cell membrane, they only need lower energy, such as T = 25℃, 0.5nm of pore radius, ion′s energy decreased from 65.5kT into 11kT. When radius of pore enlarges into 2nm, these ion's energy inside pore will decrease to 4.68kT.

Because of ion's energy in the water is of 1.7kT, so that the energy passing through membrane only needs 2.93kT, which nearly equals to 3/2kT of thermal motion. In the case, some ions easyly pass through lipid bilayer membrane. The radius of eletroporation always is from 1nm to 40nm, which can resuet in the most of ions and molecules passing through the membrane. so that rupture of cell membrane will be generated.

[1] WANG Baoyi, YANG Jiebin, GUO Qinggong et al;

Experimental study and mechanism analysis on bioeffects by nanosecond electromagnetic pulses. Science in china (Series c). 1997.40(3):301~304

[2]Weaver.J.C; Electroporation in cells and tissues; A biophysical phenomenon due to electromagnetic fields, Radio Science, 1995, 30(1):205

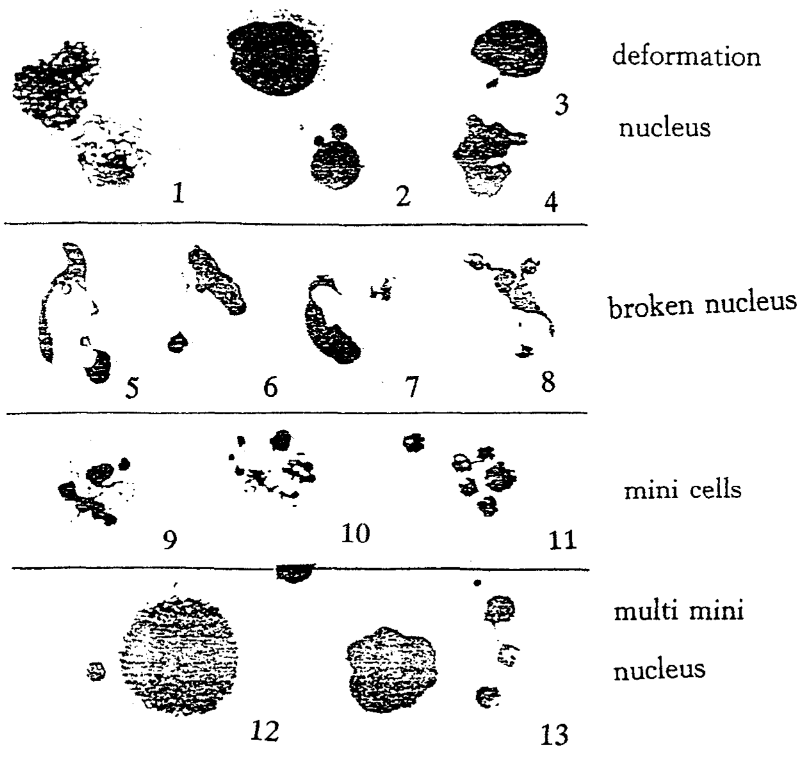
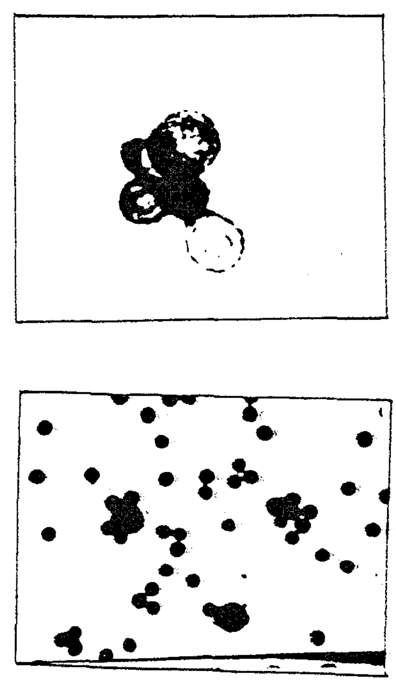


Fig.1.



E — rosette

Fig. 2