Electrostatic Field Induced Changes in Mouse Serum Proteins

The use of electricity in biological reasearch and medicine holds great promise. Direct current effects[1,2], piezoelectric[3,4] and electromagnetic radiation effect[5] may all prove useful or significant. A coherent theory of the effect of electricity on living tissue will be greatly aided by a determination of the range of experimentally observable effects. We report here that the serum protein patterns of mice are altered by continuous full-body exposure to electrostatic fields for periods up to 21 days. The result establishes that electrical effects can occur in mammalian systems at low energy thresholds, and in the absence of applied current.

The serum electrophoresis patterns of mature female Swiss Ha/ICR mice were studied after 7,14 and 21 days of exposure to electrostatic fields of 2.7×10^3 volts/m and 10.7×10^3 volts/m applied parallel to the earth's surface (E_{II}) and of 5.7×10^3 volts/m applied perpendicularly ($E_{\perp}$). Many of the details of the apparatus and the electrophoretic procedure are described elsewhere[6]. At each field strength and time interval, 5 mice were sacrificed and the sera from each group were pooled and frozen until studied. The control group recovered at each time interval was treated exactly as the corresponding experimental groups. 5 aliquots of sera were electrophoresed on cellulose acetate. Relative protein percentages were determined by measuring optical density along the stained cellulose acetate strips and integrating planimetrically. The patterns observed were similar to those described by HEREMANS et al.[7] and we have adopted their assignment of the different protein peaks. The strips were scanned twice and each scan was integrated twice. Averages were then taken over the 20 sets of data for each pool. The mice were caged normally and fed ad libitum during field exposure.

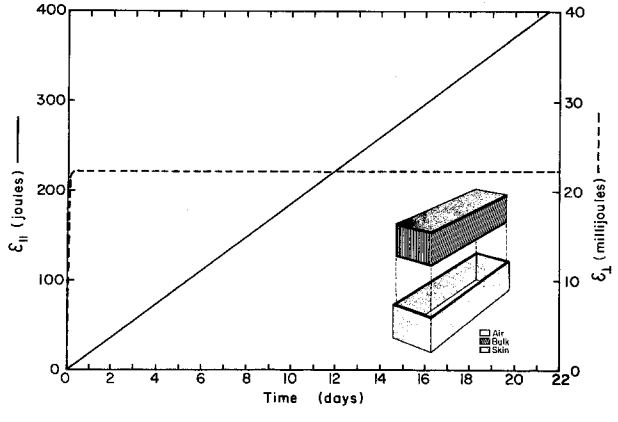
The Table, shows that the β-proteins are most affected by electrostatic fields. When compared to the controls, the relative percentage of the β-proteins increased at the higher parallel field at day 7 and the increase persisted at day 14 and day 21. At day 21, an increase in the relative percentage of the β-proteins appeared at the lower parallel field, while a decrease appeared at the peperndicular field. The serum protein changes seem to have occurred at the expense of the corresponding albumin fractions. The onset of a β-protein effect at the lower parallel field at day 21 raises the possibility that longer exposures may produce effects at still lower fields.

To obtain some idea of the energies involved in the field exposure experiments, we modelled the mouse as a rectangular solid surrounded by a layer of skin (Figure). In such a model energy is dissipated via the charging and discharging of air-skin and skin-bulk interfaces. There is also a stored energy in both media and in both types of interfaces. We discuss here the salient features of the calculations for the energies dissipated and stored for both directions of the electrostatic field. Details will be given elsewhere[8].

In a perpendicular field all interfaces charge continuously, independently of the mouse's motion. The cumulative energy dissipated in the mouse's bulk at $E_{\perp} = 5.6 \times 10^3$ volts/m is shown in the Figure. The cumulative energy dissipated in the skin is of the order of 10^{-17} joules and is therefore negligible. Of no consequence also are the energies stored in the bulk (10^{-18} joules) and in the skin (10^{-29} joules). In a parallel field the interfaces alternately charge and discharge depending on their angular relationship to the electrostatic field. Assuming a daily schedule of activity in which the mouse makes 144 circuits of the periphery of its cage at a speed of 0.1 m/sec the average cumulative energy dissipated in the bulk at $E_{II} = 10.7 \times 10^3$ volts/m is shown in the Figure. Again the energy dissipated in the skin and the energies stored are negligible. For both fields, the energy stored in the interfaces is of the order of 10^{-3} joules.

The calculations indicate that at $E_{II} = 10.7 \times 10^3$ volts/m about 18.7 joules/day are imparted to the mouse. By comparison, this is only 0.02% of the energy value of its daily food intake. It therefore seems reasonable to conclude that the β-protein effect in the mice exposed at $E_{II} = 10.7 \times 10^3$ volts/m is an informational effect as that term is used by PRESMAN[9]. The calculations also show that for equal field strengths much more energy would be dissipated in a parallel field than in a perpendicular field.

It seems certain that further work employing our relatively simple experimental system and its associated physical model will yield insight into the nature of some of the effects produced by physically invasive techniques[10].



Calculated cumulative energies dissipated by a mouse in an electrostatic field. Assumed values of the dielectric constant and resistivity were: for the skin, 10^7 and 0.1 mho/m, for the bulk, 80 and 1.0 mho/m[9]. ε_{II} is the average cumulative energy dissipated in a motional mouse's bulk at $E_{II} = 10.7 \times 10^3$ volts/m. $\varepsilon_{\perp}$ is the cumulative energy dissipated in a mouse's bulk at $E_{\perp} = 5.6 \times 10^3$ volts/m. The assumed physical model of the mouse is shown in the insert.

1 C. A. L. BASSETT, R. PAWLUK and R. O. BECKER, Nature, Lond. *204*, 652 (1964).

2 L. LAVINE, I. LUSTRIN, M. SHAMOS, R. RINALDI, and A. LIBOFF, Science *175*, 1118 (1972).

3 C. A. L. BASSETT, Calc. Tiss. Res. *1*, 252 (1968).

4 E. FUKADA, Biorheology *5*, 199 (1968).

5 M. TOLGSKAYA and S. GORDAN, *Pathological Effects of Radio Waves* (Consultants Bureau, New York 1973).

6 A. MARINO, T. BERGER, J. MITCHELL, B. DUHACEK and R. BECKER, Ann. N.Y. Acad. Sci., in press

7 J. HEREMANS, J. CLAUSEN, M. HEREMANS and R. RASK-NIELSEN, J. natn. Cancer Inst. *22*, 45 (1959).

8 F. HART, A. MARINO, T. BERGER and R. BECKER, in preparation.

9 A. S. PRESMAN, *Electromagnetic Fields and Life* (Plenum Press, New York 1970).

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Serum protein relative percentages for mice exposed to parallel (E_{II}) and perpendicular ($E_{\perp}$) electrostatic fields

Electrostatic field (volts/m)	Albumin	α	β	γ
7 Days				
$E_{II} = 2.7 \times 10^3$	65.3 ± 1.7	10.0 ± 2.3	18.5 ± 1.2	6.2 ± 0.7
$E_{II} = 10.7 \times 10^3$	59.1 ± 5.3	11.4 ± 2.0	22.0 ± 2.0[a]	6.9 ± 1.4
$E_{\perp} = 5.7 \times 10^3$	62.2 ± 2.3	12.1 ± 1.0	17.3 ± 0.8	8.5 ± 1.0[a]
Control	63.9 ± 3.8	12.6 ± 0.6	17.6 ± 0.6	6.0 ± 1.0
14 Days				
Electrostatic field (volts/m)	Albumin	α	β	γ
$E_{II} = 2.7 \times 10^3$	58.6 ± 3.4	14.0 ± 2.5	20.3 ± 2.3	7.7 ± 1.3
$E_{II} = 10.7 \times 10^3$	56.2 ± 2.6	13.9 ± 1.4	22.7 ± 1.4[a]	7.2 ± 1.4
$E_{\perp} = 5.7 \times 10^3$	57.9 ± 3.3	16.0 ± 1.2	20.7 ± 1.8	5.3 ± 1.4
Control	56.3 ± 4.0	17.4 ± 3.9	19.8 ± 1.8	6.3 ± 2.0
21 Days				
Electrostatic field (volts/m)	Albumin	α	β	γ
$E_{II} = 2.7 \times 10^3$	57.7 ± 2.0	13.3 ± 1.0	23.3 ± 1.1[a]	6.0 ± 1.2
$E_{II} = 10.7 \times 10^3$	54.6 ± 2.8[a]	15.0 ± 1.4	24.1 ± 1.0[a]	6.4 ± 1.5
$E_{\perp} = 5.7 \times 10^3$	61.8 ± 1.5[a]	13.1 ± 0.6	19.0 ± 1.4[a]	5.9 ± 0.7
Control	58.6 ± 1.5	13.4 ± 1.2	21.6 ± 1.1	6.2 ± 1.5

[a] $P < 0.05$ for a two-tailed t-test.

Résumé. Chez des souris ayant été exposée sur tout leurs corps aux champs électrostatiques parallèles à la surface de la terre, le pourcentage relatif des β-protéines de leur sérum s'élève. Nos calculs montrent que l'énergie délivrée par ces champs est négligeable. Son effet sur les β-protéines ne paraît donc pas être le résultat d'un transfer d'énergie, mais plutôt un effet informationnel.

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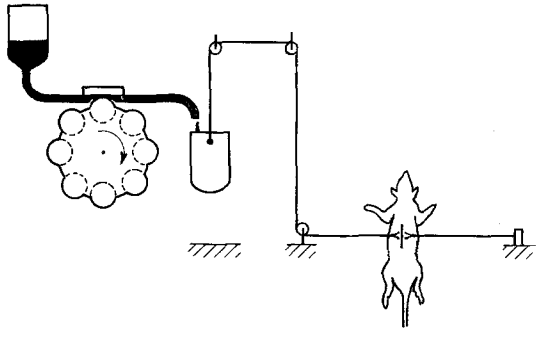
Stimulation of Wound Healing with Laser Beam in the Rat

In the preceding works it was demonstrated that the healing of surgical wounds induced in laboratory animals was enhanced by laser irradiation[1,2]. The promoting effect of laser beam on wound healing has been confirmed in the clinics: so far 26 cases of clinical healing have been reported[3]. The wounds healed by laser beam had previously failed to respond to usually applied methods, included plastic surgery. The aim of the present experiment was to study the effect of laser beam on wound healing by the simple method of determining tensile strength (TS).

Sprague-Dawley (CFY) male rats of 150 + 10 g were used. Depilation along the dorso-lumbar region was performed with an electric clipper and depilatory cream. A slit (2.5 cm long) was cut into the skin of the central line, whereafter the edges of the wound were closed with 2 Michel wound clips. The wound surface of 1 cm length between the two clips was exposed to laser beam twice for 3 min, daily. The source of radiation was an He-Ne gas-laser (Hungarian Optical Works, 5 mW energy output power). For the time of irradiation, the animals were anaesthetized with nembutal (40 mg/kg, i.p.), the controls being given similar treatment. The first dose of laser beam was timed for 4 h after incision of the wound. 3, 5, 8 and 12 days after having been wounded, respective groups of



Simple tensiometer for laser beam measurement.

[1] E. Mester, T. Spiry, B. Szende and J. G. Tota, Am. J. Surg. *122*, 532 (1971).
[2] E. Mester, B. Szende, T. Spiry and A. Scher, Acta chir. hung. *13*, 315 (1972).
[3] E. Mester, E. Bácsy, A. Korényi-Both, I. Kovács and T. Spiry, Arch. klin. Chir., Suppl. Chir. Forum (1974), p. 261.