Gastrointestinal Motor Activity Following Exposure to a High-Frequency Electric Field[1]

A quantitative evaluation of the gastrointestinal effects of a high-intensity high frequency electric field is described. The study was divided into two complementary phases: first, an evaluation of acetylcholine responsiveness of intestinal muscle strips in an isolated tissue bath and, secondly; a comparison of the measured differences of Evans Blue dye in various portions of the gastrointestinal tract at selected intervals following exposure to the field.

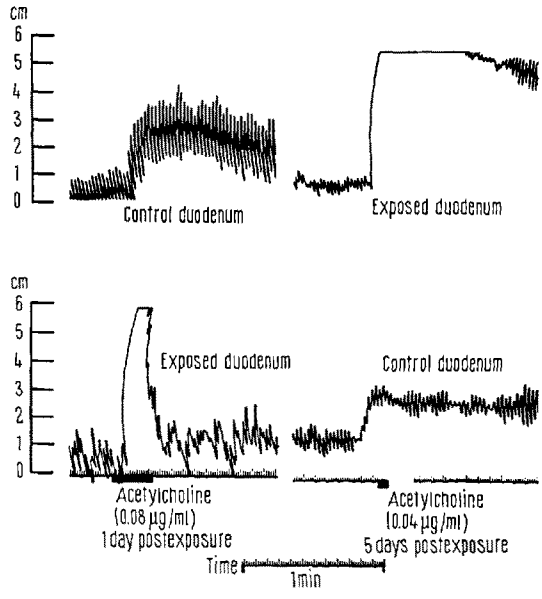
Materials and methods. 110 adult male Sprague-Dawley rats were used. All animals were exposed for 30 min to a 6.0 MHz electric field between a pair of large condenser plates. The plates measured 1.7 m long, 0.61 m wide, and with an average spacing of 0.32 m. This exposure device was located in one corner of an electrically-shielded room. A quasi-static computation of the electric field existing between the plates was of the order of 1500 v/m. Q-meter measurements indicated that the electric power dissipated by each animal was less than 1 watt. During exposure the animals showed no overt signs of discomfort.

In the motility experiment the animals were sacrificed by stunning at stated intervals following exposure. Muscle strips from the duodenum and jejunum were removed and suspended in an oxygenated bath of Tyrodes solution at 37 °C. Each experimental strip was paired with a muscle strip from a sham-exposed animal in the same vessel so that differences in response could be observed. The force transducers to which the strips were connected were calibrated with the same weight before the experiment so that force measurements would be comparable. After equilibration acetylcholine chloride was added directly to the bath and the heights of contraction of the 2 strips were used as measures of responsiveness.

Propulsive motility was examined by intubating animals with 0.5 ml of Evans Blue dye immediately after exposure or sham exposure. Animals were sacrificed at intervals of 1, 2, 3 and 6 h following intubation and the dye contents of the stomach, small intestine, and colon were measured according to a previously-published method[2].

Results and discussion. In all cases muscle strips from the small intestine of exposed animals showed a greatly increased strength of contraction in response to a test dose of acetylcholine. This response was present for 5 days following the experimental treatment (Figure). Muscle strips from the colons of exposed animals either failed to show increased contractile force to acetylcholine or showed a decreased response when compared to the controls.

The results of the dye-transit studies are shown in the Table. It was determined that at both 2 h and 3 h after intubation, the stomachs of the exposed rats lost significantly more dye on the average than did the stomachs of the sham controls. During these 2 and 3 h periods, the co-



Response to acetylcholine of isolated strips of duodenal muscle. Same magnification of recording levers.

[1] Supported by Contract No. IA-14121 from the United States Information Agency. The authors are indebted to Mrs. EILEEN MILLER for her valuable technical assistance.

[2] R. D. GOODMAN, D. E. LEWIS, E. A. SCHUCK and M. A. GREENFIELD, Am. J. Physiol. *169*, 236 (1952).

Average values of Evans Blue dye content (mg) in the gastrointestinal tracts of sham control and high-frequency exposed rats

	Sham group N	$\bar{X}_1$	S_1^2	Test group N	$\bar{X}_2$	S_2^2	Joint statistics S.E.D.	$\bar{X}_1-\bar{X}_2$
	1 hour							
Stomach	5	7.20	11.98	5	4.66	1.62	1.65	2.54
Small intestine	5	5.52	3.17	5	6.38	1.64	0.98	–0.86
Colon	5	0.48	0.04	5	1.20	1.10	0.48	–0.72
	2 hours							
Stomach	5	5.28	3.39	5	2.00	0.81	0.92	3.28*
Small intestine	5	7.18	6.90	5	4.46	2.83	1.40	2.72
Colon	5	1.30	0.66	5	3.42	3.40	0.90	–2.12*
	3 hours							
Stomach	5	4.20	3.96	5	0.78	0.80	0.98	3.42*
Small intestine	5	5.02	7.16	5	2.38	2.12	1.36	2.64
Colon	5	2.50	3.87	5	7.24	6.51	1.44	–4.74*
	6 hours							
Stomach	5	0.84	0.54	5	0.84	0.54	0.37	0.00
Small intestine	5	3.44	16.34	5	1.12	0.72	1.85	2.32
Colon	5	3.28	4.53	5	1.74	0.73	1.03	1.54

*Significant at the 0.05 level.

lons of the exposed animals collected more dye on the average than did the colons of the controls. These differences of average values were significant at the 5% level of confidence under the null-hypothesis that no difference of averages would exist.

In sum, gastrointestinal transit data is in agreement with small intestinal motility patterns obtained from rats which were exposed to a high frequency electric field. The hypomotility and low responsiveness to acetylcholine which is manifested by isolated strips of large intestine from exposed animals is consistent with the observation that no animals exposed to these general radio-frequency parameters was ever observed to exhibit diarrhea. It is felt that these data definitely constitute the first demonstrable evidence warranting the inference of a possible relationship between exposure to a high-frequency electric field and gastrointestinal effects. No speculation upon the mechanistic aspect of this relationship is warranted at this time.

Zusammenfassung. Nachweis, dass die Exposition von männlichen Sprague-Dawley-Ratten im hochfrequenten elektrischen Feld zu Veränderungen der gastro-intestinalen Motilität führt.

M. F. TANSY, F. M. KENDALL, J. CHRYZANOWSKI, F. J. HOHENLEITNER and A. R. KALL[3]

Department of Physiology
Temple University Schools of Dentistry,
Pharmacy and Allied Health Professions,
Philadelphia (Pennsylvania 19140, USA),
22 March 1971.

[3] Present address: Ark Electronics, Willow Grove, Pennsylvania.

Sensitivity of Sodium Efflux in Barnacle Muscle Fibers to the Microinjection of Calcium Chloride

In the course of an enquiry into the behavior of Na efflux in barnacle muscle fibers bathed in artificial sea water it was found that the extrusion of sodium was greatly stimulated by an injection of $CaCl_2$. It was concluded from this that the Na efflux mechanism consists of a component which is Ca^{2+}-sensitive. However it was unclear whether injections of $CaCl_2$ would bring about a similar effect on Na efflux into K-free artificial sea water. In the present experiments, therefore, an attempt was made to uncouple the Na-K transport system of these fibers before microinjecting a solution of $CaCl_2$.

These experiments were done using single muscle fibers isolated by dissection from the depressor muscle bundles of the barnacle *Balanus nubilus* (or *B. aquila*). The fibers were cannulated in the same way as *Maia* fibers and then loaded with ^{22}Na by means of a HODGKIN and KEYNES[1] microinjector as modified by CALDWELL and WALSTER[2]. The injector discharged ca. 0.1 µl of test fluid/cm of micromanipulator. The experiments were done in artificial sea water as the bathing medium, the composition of which was: (m*M*) NaCl 465, KCl 10, $MgCl_2$ 10, $CaCl_2$ 10, $NaHCO_3$ 10, pH 7.8 and the temperature of this medium was between 22 and 23 °C. K-free artificial sea water solutions were prepared by substituting NaCl in equimolar amount.

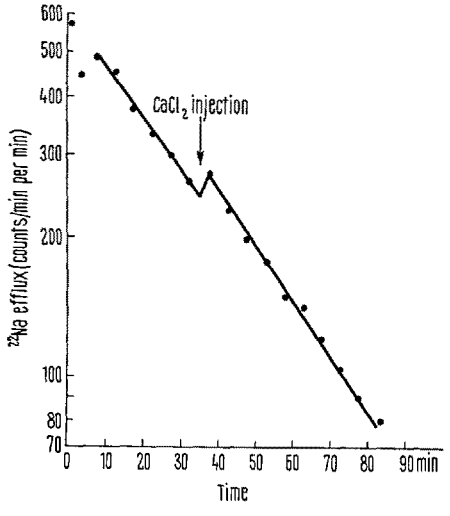


Fig. 1. The behavior of Na efflux from a barnacle fiber in artificial sea water before and after internal application of 1 *M* $CaCl_2$, plotted semilogarithmically.

The activity of ^{22}Na in the washings and the activity in the fiber remaining at the end of each experiment were measured using the procedures described by BITTAR[3] and BITTAR, CALDWELL and LOWE[4]. ^{22}Na (Code SKS. 1) was obtained from Amersham-Searle Corporation.

The effect on Na efflux of injecting a solution of 1 *M* $CaCl_2$ into barnacle fibers is illustrated by Figures 1 and 2. In the first Figure the Na efflux is shown to be relatively insensitive to a sudden rise in the sarcoplasmic free Ca^{2+} concentration. In the second figure however the Na efflux is shown to be greatly stimulated by a sudden rise in the internal free Ca^{2+} concentration. Also shown is that contraction (see legend) in itself leads to a slight increase in the Na efflux. This could be merely the result of the squeezing of some radiosodium out of the T-system.

The effect of K removal on the Na efflux and of injecting 1 *M* $CaCl_2$ on the residual efflux is illustrated in Figures 3 and 4. One can see that the removal of K ions from the bathing medium caused a large reduction in the loss of radiosodium. Furthermore, injection of 1 *M* $CaCl_2$ is shown to result in a rise in the Na efflux, the magnitude of the effect being quite great in Figure 4. This pattern of behavior parallels that of fibers injected with concentrations of $CaCl_2$ as low as 1 m*M*. The significance of this comparison lies in the fact that an initial

[1] A. L. HODGKIN and R. D. KEYNES, J. Physiol., Lond. *131*, 592 (1956).
[2] P. C. CALDWELL and G. E. WALSTER, J. Physiol., Lond. *169*, 353 (1963).
[3] E. E. BITTAR, J. Physiol., Lond. *187*, 81 (1966).
[4] E. E. BITTAR, P. C. CALDWELL and A. G. LOWE, J. mar. biol. Ass. U.K. *47*, 709 (1967).