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Changes in Temperatures of Tissues After Systemic Applications of Short Wave Electric Fields.

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The apparatus used in these investigations is a product of the Research Laboratories of the General Electric Company and, through the courtesy of this company, was made available to us for experimental work. Essentially, the apparatus is a short wavelength radiogenerator, the output of which is fed to large condenser plates rather than to an antenna. The electric energy is available over a wavelength range of 7.5 to 20 meters, with an approximate power output of 150 to 400 watts. Throughout these investigations we have used a frequency of 27.5 million cycles per second (wavelength of 10.9 meters).

Measurements of temperatures of tissues have been made by means of special detachable thermocouples incorporated in the electromotive thermometer.[1] Rectal temperatures were obtained by means of an automatically recording resistance thermometer (Brown Instrument Company).

The application of energy between the primary condenser plates of the oscillator to dogs with distemper—the plates of the oscillator extended along the body of the animals from neck to knee in all these experiments—showed that the rectal temperatures increased from 1.5° to 2°C. under a divided dosage of approximately 10 minutes of radiation over a 20-minute interval. The increase of temperature was uniform per unit of applied electric energy until a rectal temperature of 40°C. (104°F.) was obtained; after that the increase of temperature per unit of energy decreased. In dogs with distemper, it was found that mucus was mobilized markedly during the first few treatments in the electric field. After five or six exposures of the animal to radiothermy, no mucus was in evidence.

One animal was given the usual 10-minute body treatment in the electric field. The rectal temperature rose 1°C., and within 5 minutes after discontinuation of the treatment the temperature began to drop exponentially with the passage of time. The following day this same animal was anesthetized by means of an intravenous injection of sodium amytal (sodium isoamylethylbarbiturate). Given an identical 10-minute treatment, the rectal temperature of the dog

[1] Sheard, Charles, *Am. J. Clin. Path.*, 1931, **1**, 209.

rose 2.5°C. and remained at this peak for 30 minutes before the exponential loss of heat began to occur. Measurements on temperatures of tissues of the upper part of the leg of this animal showed that the intramuscular and subcutaneous temperatures paralleled the rectal temperature after treatment, but that the intramuscular temperature remained approximately 0.5°C. above the rectal, whereas the subcutaneous temperature remained about 0.2°C. below the rectal. Similar results were obtained in other dogs.

Measurements of temperatures of tissues were made on a series of dogs in which a general hyperthermia was produced by means of the short wave field. Before treatment, the intramuscular temperature ordinarily was found to be slightly higher than the rectal temperature, whereas the subcutaneous temperature was usually slightly lower than the rectal. The intramuscular temperature of the upper part of the legs of the dogs was generally found to be between 39° and 39.5°C. (102.2° and 103.1°F.) and approximately 1°C. higher than the subcutaneous temperature. With thermocouple needles in the tissues during oscillation of the field, both intramuscular and subcutaneous temperatures of the tissues rose rapidly. When application of the field was discontinued, both tissue temperatures dropped steeply along an approximately exponential path. However, the intramuscular temperatures remained constantly above the subcutaneous values, and while the subcutaneous temperatures dropped to the rectal level, or slightly lower, within 5 to 10 minutes after discontinuation of the treatment in the electric field, the intramuscular temperatures remained constantly above the rectal temperatures.

In a number of experiments the changes of temperature induced in the tissues at the knee joints of dogs were compared with those induced in the muscle tissues of the upper part of the leg. The normal intra-articular temperature was approximately 2°C. less than the intramuscular temperature. When thermocouples were present in the tissues during oscillation of the high-frequency field, the rise of temperature in the intra-articular regions was much sharper than in the intramuscular tissue, but the subsequent fall in temperature was also more rapid. Five minutes after the treatment had been discontinued, the intra-articular temperature attained a fairly constant value which remained approximately 1°C. below that attained by the intramuscular temperature. There was a decided increase in the intra-articular temperatures as compared to both rectal and intramuscular temperatures.

Small holes were drilled in the bone of the leg of a dead animal.

Measurements of temperature were made before and after exposures of the limb to the short wave field. The temperature of intramuscular tissue was found to be 32°C. (89.6°F.); temperatures of bone in 2 different regions were found to be 30°C. and 33°C. (86° and 91.4°F.) respectively. Applications of the high frequency field for 5 minutes produced an increase of 1.2°C. in the temperatures

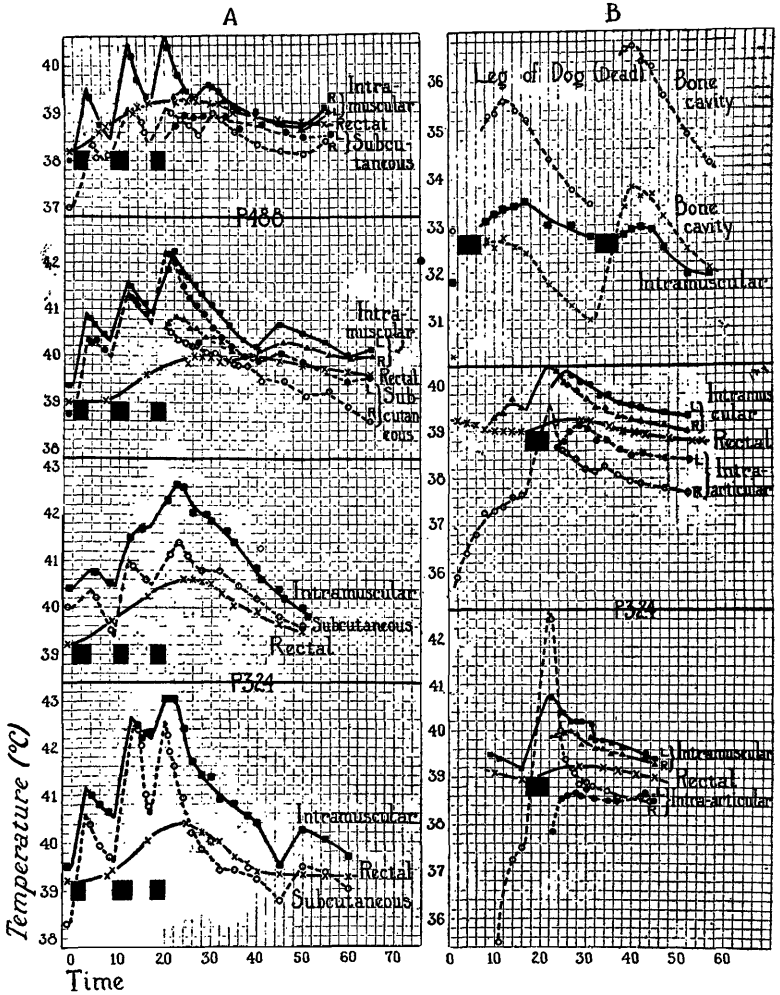

FIG. 1.

Curves showing the comparative heating of living tissues in the high-frequency field. Part *A*. Effects on intramuscular and subcutaneous temperatures. Part *B*. Effects on intra-articular (knee joint) and intramuscular temperatures as compared with rectal temperatures. Each group of curves shows the changes in temperature obtained when thermocouples were inserted in the tissue (1) throughout the period of application of the field and (2) after the cessation of application of the field. Time of treatment and chronological order are indicated by the blackened rectangles.

of muscle tissues and of 3.3°C. in the temperatures of both portions of the bone under test.

Conclusions. These experimental data show that, in living animals, the temperatures of certain different types of tissues are affected to different degrees by the systemic application of the short-wave electric field. Muscle tissue is affected slightly more than is subcutaneous tissue; intra-articular tissue is affected more than is muscle tissue. Furthermore, it has been shown that the reactions of anesthetized animals to general hyperthermia produced by this physical agent (short electric wave fields) are quantitatively different from those produced in unanesthetized animals. Measurements of temperatures of tissues of dead animals have shown that bone is heated much more markedly than is muscle tissue and they have indicated that the changes of temperature produced by this high frequency field are strictly dependent on the position and constitution of the various tissues.

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Thermal Changes Produced in Tissues by Local Applications of Radiothermy.

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The short electric wave generator developed in the Research Laboratories of the General Electric Company was used in these investigations. In utilizing the energy of this high frequency field for the investigations of thermal changes produced by local applications of the field, small insulated condenser plates were attached by means of tubular telescopic rods to the large condenser plates.

Measurements of temperatures were made (series of 30 dogs) on the intra-articular and subcutaneous tissues of both knee joints of each animal after local application of the short wave field to the region of the knee joints. Condenser plates 2.5 by 3 inches, separated by distances which varied from 2.5 to 4 inches, produced the high frequency field into which was placed the part of the animal to be tested. The current density applied to the knee joints varied from 0.1 to 0.05 ampere per square inch of surface of the small auxiliary condenser plates. The frequency of oscillation of the electric field