THE PRODUCTION OF FEVER IN MAN BY SHORT RADIO WAVES

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THE value of heat as a physical means of alleviating and curing disease has been emphasized constantly throughout the history of medicine. However, the significance of fever and its relation to the course of an infectious disease or to the healing of trauma has been debated often. It was believed that a rise in body temperature was only a sign of disease, as is pain, and, to establish the comfort of a patient, must be dissipated. Nevertheless, evidence has been accumulated during the last few years to show that a fever, disregarding hyperpyrexia of central origin, may be a phenomenon valuable to the diseased animal body. It is a very complex factor in which an increased amount of heat stored in the body is its chief manifestation. In this report it is impossible to tabulate all the facts substantiating the value of fever in the course of a disease, but we premise that it is a defensive mechanism for the body.

To raise the body temperature of laboratory animals such as mice, rats, guinea-pigs, rabbits, dogs, etc., is comparatively simple. Their mass is small and they are not so able to eliminate effectively an increased amount of heat as is man. They have a hairy coat and do not possess the great areas of sweat glands with such an extensive peripheral vascular bed. However, these factors may make such heatings more hazardous to the life of the animal.

Many investigators have described methods for heating the human body locally or generally. Local heating is easily accomplished, but since man's temperature-regulating mechanism is so efficient the elevation of a normal temperature is comparatively difficult. Because so much time has been required in the past to do this, the therapeutic application of artificial fevers has not been practical. Various physical methods have been employed. Hot water baths have been used successfully by Schamberg and Tseng[1] and by Mehrtens and Pouppirt.[2] Exposure of the body to artificially heated, dry and moist atmospheres has frequently been used in an attempt to raise the body temperature. Recently diathermic methods for producing artificial fevers have been developed. Nagelschmidt[3] as well as King and Cocke[4] have described special apparatus and methods for applying this energy for therapeutic purposes. The latter state that after a rise of one or two degrees during the first half hour or hour, they usually obtained a rise of .6 degrees F. for every fifteen minutes. While the physicist and those engaged in developing physical therapy have been conducting such experiments the bacteriologist and immunologist have also been studying this same problem. For a long time they have known that the injection of a protein, usually foreign, used as a diagnostic agent or as a therapeutic agent, will destroy the equilibrium between heat production and heat loss in the body and result in a fever with other symptoms characteristic of those observed in an acute infectious disease. Combinations of certain diseases occurring in the same individual, *i.e.*, an acute febrile disease with a chronic afebrile malady, sometimes resulted in an improvement or a cure of the latter. Such observations played an important rôle in Wagner von Jauregg's[5] development of the malaria treatment for paresis. Because of his success the study of the value of fever in an infectious disease syndrome is engaging the attention of many investigators. That the heat associated with the febrile phenomenon due to the injection of a protein is the factor that is responsible for the beneficial results is suggested by the favorable results obtained in the treatment of neurosyphilis by heat alone. The present methods that are used to establish fever in man are unsatisfactory in one respect or another. The injection of foreign proteins is hazardous because one is dealing with unknown factors and uncertain quantities. The use of Plasmodium malariae or spirochaetes for the treatment of general paresis often fails because of the danger concerned with the administration of a living virus and because of a failure to infect immune individuals. The physical methods employed are time-consuming, difficult of application, not easily controlled and, to a certain degree, dangerous.

Since the observation of Dr. W. R. Whitney, director of the research laboratories of the General Electric Company, that there is an elevation of the body temperature of men working in the field of a short wave radio transmitter, considerable experimental work has been undertaken to adapt this energy for producing artificial fevers. Hosmer[6] has reported

[1] Schamberg and Tseng, *Am. J. of Syphilis*, 11: 337, 1927.

[2] Mehrtens and Pouppirt, *Arch. Neurol. and Psych.*, 22: 700, 1929.

[3] F. Nagelschmidt, *Deutsch. Med. Wchnr.*, 54: 2102, 1928.

[4] King and Cocke, *Southern Medical Journal*, 23: 222, 1930.

[5] J. Wagner-Jauregg, *Psych.-Neurol. Wchnr.*, 20: 132, 1918.

[6] H. Hosmer, SCIENCE, 68: 325, 1928.

these heating effects on salt solutions of various concentrations and on small laboratory animals. She determined that this is a method for producing in animals any degree of fever at will without the introduction of foreign substances. The heat is produced directly within the animal body, as occurs in the course of a fever due to an infectious disease. This constitutes a method for internal heating in which the heat is generated in the organs of the body as rapidly as in the body walls, but because of the greater heat loss at the periphery the temperature of the internal tissues rises more rapidly.

During the last two years special types of apparatus have been designed by the research laboratories of the General Electric Company and used experimentally in an endeavor to cause a fever in man rapidly without great discomfort to the patient and to a degree high enough to be of value. The equipment used in our experiments has been constructed on the same principle as a short wave radio transmitter, with the exception that the energy is concentrated between two condenser plates instead of being directed from an aerial. The heater consists of a vacuum tube oscillator and a full wave rectifier that supplies the high voltage for the oscillator. The high frequency oscillator is composed of two 500 watt radiotrons operating at a frequency of from 10,000 to 14,000 kilocycles, the output of which is concentrated between two plates. The rectifier is an oil immersed transformer having a 7,000 volt secondary and feeding two half-wave, hot cathode, mercury vapor tubes. In conjunction with a filter system this unit furnishes the 3,000 volt D. C. plate supply for the oscillator. An auto-transformer is connected on the primary circuit of the high voltage transformer to provide plate voltage regulation.

The condenser plates are of aluminum, 28″ by 18″ by ⅛″, and are covered with hard rubber plates 30″ by 20″ by ¼″ to prevent arcing should the patient or attendant come in contact with the plates. In this field of undamped waves between the plates there is a rapid alternation of 3,000 volts drop of potential. We have obtained our greatest heating from the use of a 30 meter wave that oscillated 10,000,000 times per second between the plates. We have used wavelengths of 6, 15 and 18 meters, but they have not heated the body so effectively with the oscillator described.

The patient is suspended on interlaced cotton tapes stretched across a wooden frame 76″ by 28″ made of two by sixes. The under surface of the frame is covered with celotex one half inch thick, forming an air chamber beneath the body. A celotex cover of similar thickness, 8 inches high and one foot shorter than the frame, is fitted over it so that the head of the patient projects through an opening at one end. Thus there is formed a fairly tight air chamber around the body as it lies on the tapes. The patient rests on his back and the plates are placed at each side of the celotex box, so that the waves oscillate through the body from one side to the other. The plate distance can be varied, but as a rule has been kept at 30 inches. Two small hair driers are placed in openings at the foot, one above and one below, to circulate hot air around the body. These decrease heat loss and equalize the humidity throughout the enclosed atmosphere.

By applying the plates in this manner and by enclosing the body, it is heated rapidly without causing great discomfort to the patient. We have raised the normal rectal temperature of 99.6 degrees F. to 104 degrees F. and 105 degrees F. in from sixty to eighty minutes. In one instance a temperature of 106.5 degrees F. was recorded. Higher temperatures may be obtained easily with the apparatus employed, but, because of our limited experience, we have proceeded cautiously. When the desired temperature is reached it may be maintained in several ways: First, by decreasing the voltage; second, by increasing plate distance; third, by employing only the hot air blowers.

The temperature recedes very slowly to normal if the patient is allowed to remain in the box or if he is removed from the box and wrapped in heated, heavy woolen blankets, which is more comfortable for him. There is, of course, an increase in rate of pulse and respiration which, in general, corresponds to the rise in temperature. The patients begin to show hyperpnea at 104 degrees F., which becomes greater as the high temperature is prolonged. Occasionally one states that he feels nauseated or that his head aches. The systolic and diastolic blood pressure is decreased when high temperatures are produced. On the whole, patients do not appear to be greatly distressed or fatigued when the maximum temperature is maintained for one hour and then allowed to return to normal while the patient is well blanketed. We believe that the condition of our patients after treatment is much more satisfactory than that reported by investigators who have used other methods to produce artificial fevers.

We have also placed the plates above and below the body so that, as the patient lay on his back, the waves were oscillating from front to back and *vice versa,* but we were not successful because of peripheral burns from arcing. Various other methods to prevent heat loss from the body during the exposure, and to absorb the sweat, have been tried by us, but each has failed. Temperatures of 101 degrees F., and occasionally 102 degrees F., were attained, but as soon as there was excessive sweating, burning of the skin occurred, caused by the radio waves concentrating and arcing through a drop of sweat. The burns apparently were due to the heat from the arc as well as to the drops of sweat that were heated by the arcing.

Although it is possible to heat the body in the enclosed celotex box by the use of the short radio waves alone, time was saved by using the hot air blowers. The circulation of the hot air around the body prevented some heat loss because the air in the enclosed chamber rose from room temperature to 122 degrees F. in twenty minutes. The maximum temperature of the air in box at any time was 131 degrees F. The circulation of the air apparently keeps the humidity throughout the atmosphere in the chamber more uniform. Sweating occurred under these conditions, but the circulating hot air helped to prevent arcing and burning.

Although we are able to produce successfully artificial fevers with the radio waves as described, we realize that the equipment used and the method for applying this form of energy to heat the body can be greatly improved, and this is rapidly being done. Various theories explaining the rise of temperature of the body when exposed to short radio waves have been discussed by Carpenter and Boak[7] in another report. We believe that the development of heat is due to the resistance of the body to the conduction of current between the surfaces adjacent to the opposed plates. At each alternation of polarity of the plates the corresponding polarities are induced upon the adjacent boundaries of the interposed body and current is conducted through the material for a brief interval. The heating of solutions similar to the blood serum is dependent directly upon their electrical resistance. It has been shown that dilute solutions of different salts when of the same electrical resistance exhibit practically identical heating effects. In this report, however, we have concerned ourselves primarily with a method for raising the body temperature. Through the cooperation of Drs. D. Glen Smith and R. A. McTaggart, of Schenectady, New York, we have been able to study the effect of such heatings on patients suffering from various diseases. The use of therapeutic fevers is still in the experimental stage, but they have great possibilities if our conception of the significance of a febrile reaction is correct. We have studied the effect of fevers produced by short radio waves on various laboratory animals and on twenty-five patients, and thus far we have failed to observe any objectionable effect unless extremely high temperatures are maintained for long periods. We have proceeded, of course, with caution, and have followed closely the variations in body temperature, blood pressure, the pulse and respiration. The use of such a method demands conservatism and sound judgment because of the comparatively short time it has been studied. However, we are of the opinion that, because of the practicality of this method of heating, it may be of value not only to the clinician, but also to the physiologist, the biochemist and the bacteriologist.

Studies of infectious diseases in laboratory animals that will be reported elsewhere lead us to believe that two desirable effects are obtained by raising the body temperature. First, the increased heat within the body makes a less favorable environment for the multiplication of a virus. Second, the heat increases the rate of those chemical processes concerned with the development of immunity and with the general defense mechanism of the body against infectious agents.

We are grateful to Dr. W. R. Whitney, director of research of the General Electric Company, and to Mr. K. C. DeWalt for their constant help and suggestions, and for the apparatus used in this work. We thank the staff of the Ellis Hospital, Schenectady, New York, for their cooperation.

[7] Carpenter and Boak, to be published in *Am. J. of Syphilis.*

SCIENTIFIC EVENTS

THE ZOOLOGICAL SOCIETY OF LONDON

THE London *Times* reports that the one hundred and first annual report of the Zoological Society of London, issued to fellows in anticipation of the general meeting on April 29, contains an appendix describing the centenary celebrations held last year. The addresses of the president on the general history of the society, and of the secretary on the scientific history, and the speeches of congratulation delivered by the chief delegates of other societies are printed in full. A list of the delegates who attended the celebrations and accounts of the dinner, at which the Prince of Wales was the chief guest, of the garden party attended by over 8,000 fellows and their friends, and of the dinner to the staff are given.

The body of the report, as usual, describes the progress of the society. The total assets amounted to £171,571, an increase of nearly £30,000 on the preceding year, but the liabilities were increased by £44,673, due almost entirely to a bank loan to defray the cost of the new refreshment rooms. On account of the tenure of the gardens, the value of buildings erected by the society can not be included in the assets. The income was £7,000 and the expenditure £5,000 less than in 1928. Rent, rates, income-tax and insurance cost over £5,000, provisions for the animals £15,500,