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A MICROWAVE APPARATUS FOR PRODUCING UNIFORM HYPERTHERMIC TEMPERATURES OVER LARGE SURFACES

F. Sterzer*, R.W. Paglione*, E. Friedenthal**, and J. Mendecki**

*RCA Laboratories, Princeton, NJ 08540
**Albert Einstein College of Medicine, Bronx, NY 10467

SUMMARY

A microwave apparatus that can produce uniform hyperthermic temperatures over large surface fields is described. The apparatus consists of a 2450 MHz power generator, a PIN diode power controller, a low-leakage non-contacting microwave applicator with an integral non-contacting infrared thermometer, a thermostat that provides feedback control and can be set to the desired tissue temperature, and a computer controlled mechanical arm that scans the applicator and the infrared thermometer over the treatment field.

Introduction

Hyperthermia cancer treatments consist of heating malignant tissues until they reach temperatures several degrees centigrade above normal body temperature and maintaining the tissues at the elevated temperatures for certain lengths of time. The procedure is usually repeated several times. Hyperthermia is given either as a stand-alone therapy, or in combination with radiotherapy or chemotherapy, or prior to surgery.

Apparatus for producing hyperthermia should be able to

(1) Raise tumor temperatures rapidly and uniformly to the desired therapeutic value,

(2) maintain tumor temperatures uniformly at the desired therapeutic value for the desired length of time, and

(3) minimize heating of healthy tissues surrounding the tumors.

The requirement for maintaining tumors at uniform therapeutic temperatures arises from the observation that the higher the minimum temperature in any part of a tumor, the better the therapeutic results.[1] If the tumor temperature is highly nonuniform, then it is difficult to reach and maintain high minimum tumor temperatures without causing unacceptable burning of the hotter parts of the tumor.

Large surface fields, such as metastatic breast cancer lesions spread over a chest wall, cannot be raised to uniform temperatures with conventional large aperture microwave hyperthermia applicators. This is because the amount of microwave power absorbed by the tissues and the amount of cooling provided by blood flow typically vary a great deal over large fields. As a result, if the tissues are illuminated with uniform microwave power densities, different parts of the tissues will usually reach widely different equilibrium temperatures.

In this paper we describe a microwave hyperthermia apparatus that, unlike conventional hyperthermia apparatus, can produce highly uniform hyperthermic temperatures over large tissue fields.

Description of Apparatus

The apparatus maintains constant tissue temperatures by means of a closed-loop control system that consists of a PIN diode controller, a non-contacting applicator with an integral infrared temperature sensor, and a thermostat (Fig. 1). The microwave power from a generator passes through the PIN diode controller into the applicator. The applicator radiates the microwave power into the tissues to be heated. Infrared radiation from the surface of the heated tissues is detected by the infrared sensor. The sensor produces an output signal that is proportional to the temperature of the surface of

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the tissues. This output signal is fed into the thermostat where it is digitized, converted to degrees Celsius, and displayed on a liquid crystal display. The thermostat also produces an error signal that is proportional to the difference between the temperature measured by the infrared sensor and the desired tissue temperature. (The desired tissue temperature is set by means of a dial on the thermostat). The error signal from the thermostat is fed into the PIN diode controller completing the control loop.

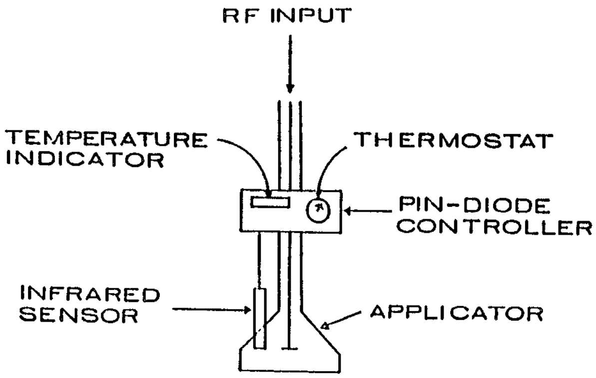

Fig. 1 Schematic of microwave apparatus for uniformly heating large tissue fields.

The applicator together with its integral infrared sensor are connected to a mechanical arm. This arm, which is under computer control, moves the applicator and the sensor in programmed repetitive sequences over the desired treatment areas. (The bottom of the applicator is typically held about 1-2 cm above the treatment area.) If the surface temperature of that part of the treatment area being viewed at a particular instant by the infrared sensor is below the preset value of the thermostat, then the control loop automatically adjusts the bias on the PIN diode controller to permit passage of microwave power to the applicator. The amount of microwave power passed by the controller is proportional to the difference between the measured and selected temperatures.

The computer controlled mechanical arm can move the applicator to any location within a 28 x 40 cm rectangular field. Several surface lesions can be treated simultaneously with this apparatus by sequentially scanning each lesion and then continuously repeating each scan.

Measured Temperature Distributions

The uniformity of the temperature distributions that the apparatus described above can produce were measured in muscle equivalent phantom and in the thigh muscle of a dog. The measurements were taken with a cw power input to the apparatus of about 50 watts at 2450 MHz. The mechanical arm was programmed to repetitively move the apparatus over the slalom path shown in Fig. 2. The time to move the apparatus over one complete slalom path was 11 seconds. After the heating was completed, surface temperatures were measured in 6.35 mm steps along the dotted path shown in Fig. 2.

In the muscle equivalent phantom [68% H_2O, 30% gelatin, 1% NaCl, 1% Formalin], for a maximum temperature rise of 7.8°C the temperature rise was uniform to within ±0.25°C over a length of 4.2 cm in the center of the dotted path of Fig. 2. A typical temperature profile measured after heating the thigh muscle of a dog is shown in Fig. 3. Note that the temperature is within ±0.1°C over a length of 4.4 cm.

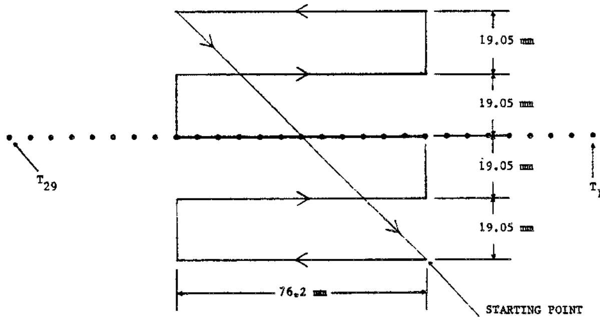

Fig. 2 Path traced by applicator over area being heated. Surface temperatures were measured along dotted line after heating was completed.

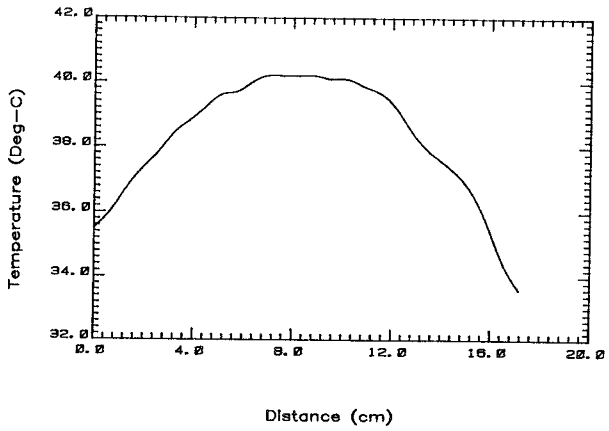

Fig. 3 Surface temperature versus distance along the dotted line of Fig. 2 measured on the thigh muscle of a dog.

Discussion

Noncontacting applicators with built-in noncontacting infrared thermometers make it possible to uniformly raise the surface temperature of large fields. When such applicators are moved by mechanical arms under computer control, several surface lesions can be conveniently treated simultaneously. The next step in the evolution of this type of hyperthermia apparatus is likely to be the addition of microwave radiometers for non-invasively measuring subcutaneous temperatures. This would make it possible to uniformly heat large subcutaneous lesions.

Acknowledgment

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References

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