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A Thermoprofile Study of 2,450-MHz Microwave Thermogenerator in Phantom and Animal Tumor

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Since March 1985, we have treated cancer patients with local hyperthermia using a 2,450-MHz microwave thermogenerator.

Prior to clinical trial, a 2,450-MHz microwave generator remodeled from a household electric range was tested and evaluated to test its clinical applicability. We studied the thermoprofile and tried to find out suitable electric power ranges to produce optimal temperature of 42~44℃ in a lump of meat, agar phantom and animal tumor models. The present study confirmed the intratumoral temperature to be 1-3℃ higher than in surrounding normal tissue.

Key Words: Local hyperthermia, 2,450-MHz microwave, Thermogenerator, Thermoprofile.

INTRODUCTION

The biologic rationale for use of hyperthermia alone or in combination with radiotherapy or chemotherapy to treat malignant tumors was well established and promising clinical results have been observed[1~2].

To obviate economical burden, we made an attempt to make use of an ordinary household electric range by partly remodeling it for clinical thermotherapy for the patients with malignant tumor at the Division of Radiation Therapy, Kangnam St. Mary's Hospital, Catholic Medical College. In addition, we constructed a microwave-guide to accurately deposit energy into defined area within a tumor.

The present communication report the results obtained from a preclinical study on thermal profiles in a lump of meat, agar phantom and animal tumor models.

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MATERIAL AND METHOD

1. Heating Device and Temperature Measurement

The microwave having 2450 MHz cycle generated by a household electric range was used for experimentation. The system was shown in Fig. 1-a and b. Heat applicator (antenna) was placed on the surface of phantom or the skin over tumor-bearing limb of a mouse, the heat was applied under the various electric power levels with continuous control of temperature by a thermometer or thermocouples. Electricity was truned off for two seconds to measure the local temperature and radial thermal distribution by pulling the thermocouple probes outwardly at 1-cm interval at the different horizontal planes.

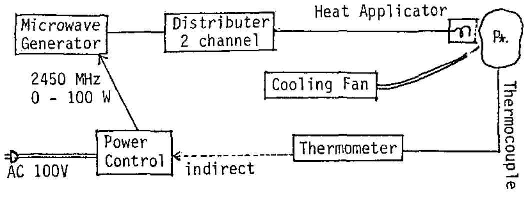

Fig. 1—a. *Block diagram of microwave generator*

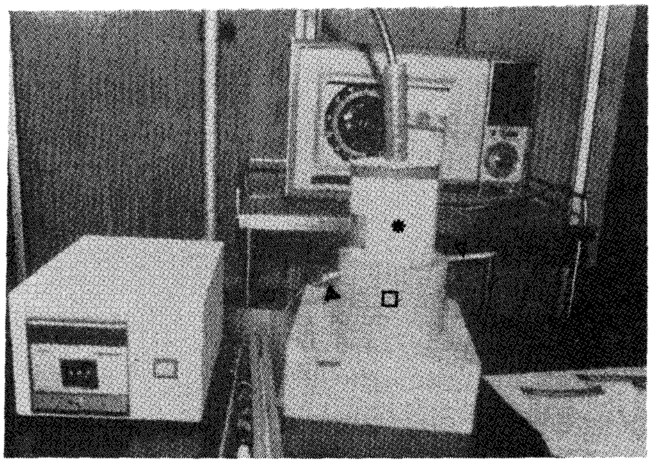

Fig. 1—b. An overview of heating a 12cm diameter & 10cm thick agar phantom (□) with 2,450 MHz microwave applicator (*). A thermometer (▽) & thermocouples (▲) were used for temperature measurement.

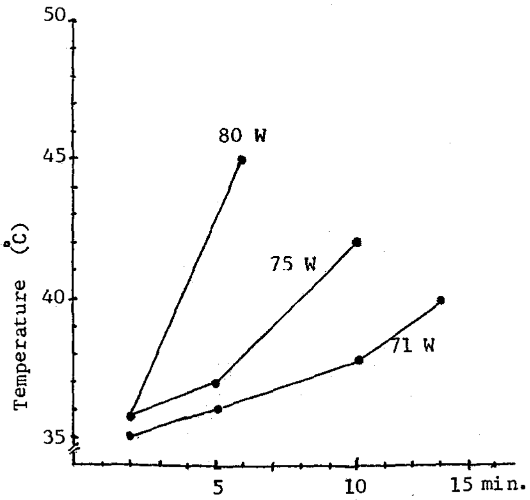

Fig. 2. Time-temperature curves in meat phantom.

2. Phantom

A cylindrical phantom, 12 cm in diameter and 10 cm in height, was made of 4% agar gel containing 0.2% Nacl.[1)]

3. Animal Tumor

Mouse sarcoma-180 tumor cells was inoculated in ascitic form at the proximal hind limb of mouse and the produced tumor mass was allowed to grow for 8 to 15 days after inoculation.

RESULTS

1. Thermoprofile in Phantom

The time-temperature curves in a meat phantom was shown in Fig. 2 and the isothermal porfile and depth thermodose in agar phantom were shown in Figs. 3-a, b, and c. A relatively homogenous depth thermodose was obtained within 3 cm in depth and somewhat hotter spot was noted just below the tip of the antenna which lay in a horizontal plane (Figs. 3-a, b and c).

2. Thermoprofile in Animal Tumor Model

Polyvinyl sheath of Angiocath®(20 gauge)containing a sensor of the thermocouples was inserted to traverse the sarcoma-bearing hind limb. The mouse was not anesthetized. The time-temperature curve in mouse sarcoma-180 heated with various energy levels was shown in Fig. 4-a. The temperature curve of the intratumoral and normal tissues during heating was shown in Fig. 4-b. The intratumoral temperature were 1-3℃ higher than in the surrounding normal tissues. To achieve the desired tumor temperature of 43°±0.5℃, microwave irradiation was required for 3 to 5 minutes while adjusting the energy requirement and fine alignment of the microwave applicator to the temperature sensing element within the tumor and adjacent normal tissues.

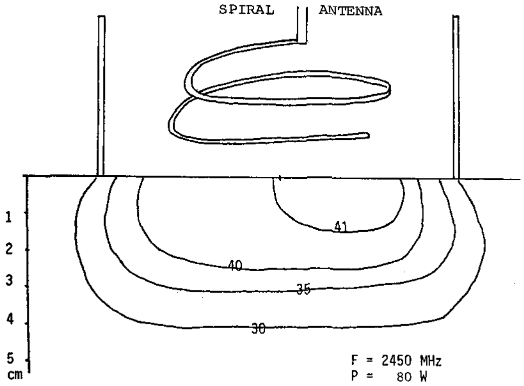

Fig. 3—a. Isothermal profiles obtained by thermocouple in agar.

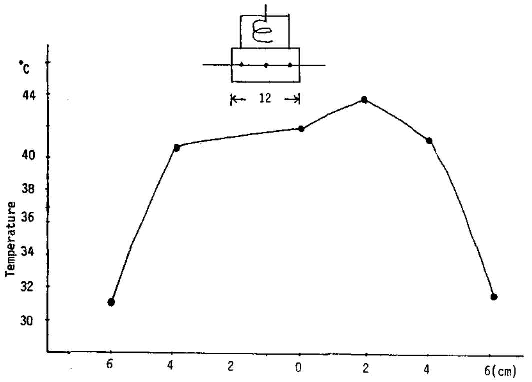

Fig. 3—b. Thermoprofile in agar phantom.

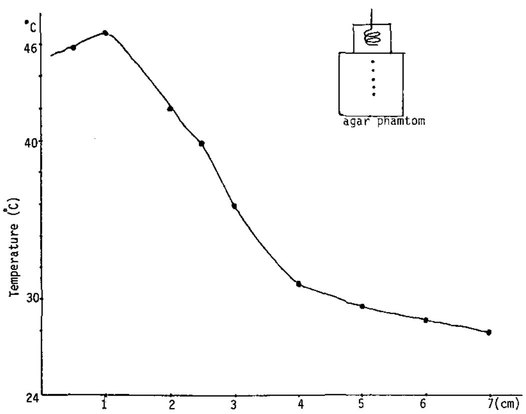

Fig. 3—c. Depth thermodose in agar phantom.

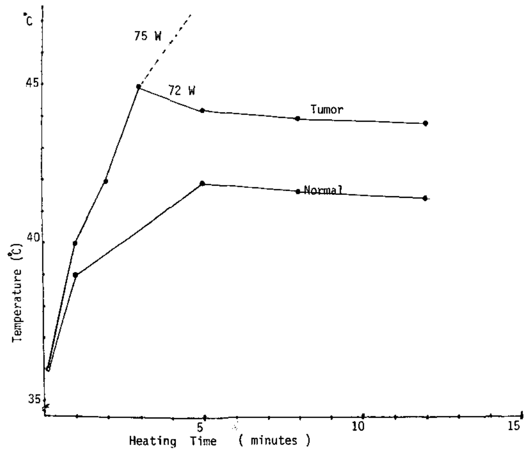

Fig. 4—a. Time-temperature curve in sarcoma 180 heat ed with various energy level.

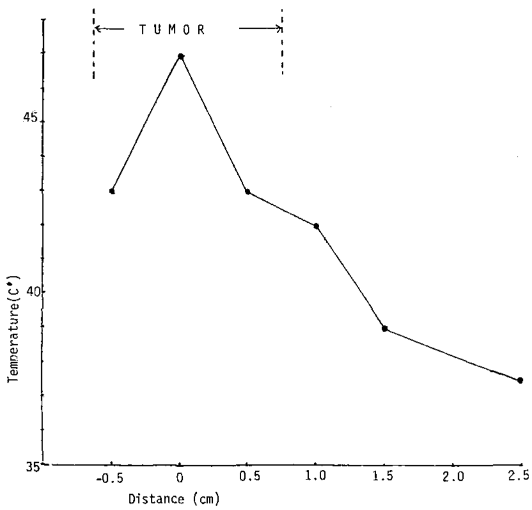

Fig. 4—b. Temperature of intratumor and normal tissue in sarcoma 180 on heating.

DISCUSSION

Microwaves are a form of electromagnetic radiation. The frequency for medical use ranges from 2,456 to 915 MHz. As with other electromagnetic waves, microwave travel at the speed of light and can be propagated through a vacum. They can be reflected, scattered, refracted or absorbed[1]. The medical use of microwaves is primarily based on the fact that they are selectively absorbed in tissues such as musculatures[1~4].

Several investigators have found that a major factor in cell killing at≧42℃ is an irreversible damage to cancer respiration[1~3]. While the exact mechanism of heat destruction remains poorly understood, coincident alteration appears to take place in nucleic acid and protein synthesis that include a reduction of activity in many vital enzyme systems[2,3]. These factors, associated with an increase in the permeability of the cell membrane and liberation of lysozymes, probably account for the autolytic cell destruction after hyperthermia[2].

The efficacy of thermocytotoxicity increases rapidly as the temperature is elevated from the 42℃ to 45℃, threshold of thermal pain in human. At such high temperatures, the differential thermosensitivity between malignant and normal cells is reduced and replaced by linear cell killing from progressive protein denaturation[2]. Thus, at≧45℃, host tissue tolerance becomes a prime concern in the design of clinical trials. On the other hand a device should be available to raise the tissue tempearature to tolerance limit and also tumorcidal levels, and potentially to overcome the cooling effect resulting from increased regional blood flow[1~3]. The meter (gauge) should show quantitatively the flow of power into the tissue, that is, it should measure the total forward output minus reflected power. An accurate time measurement should be available, too. It has been shown that the use of the lower frequency of 915 MHz would be advantageous over 2450 MHz.[3] Direct contact applicator provides better coupling and less stray radiation than standard noncontact applicator.

In our experimental model, the therapeutic effectiveness of a hyperthermia system was investigated whether it was suitable to treat the superficial cancers, and the surrounding normal tissue is 1-3℃ lower than those of intratumor in animal tumor model.

CONCLUSION

Our thermoprofile study using phantom and animal tumor models revealed that the local hyperthermia induced by 2,450 MHz microwave appears useful for the hyperthermal treatment of superficial as well as metastatic cancers. We were also able to confirm that intratumoral temperature was 1-3℃ higher than in the surrounding normal tissues.

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= 국문초록 =

2,450 MHz 온열치료기의 온도분포실험
—Phantom 및 실험동물종양에서—

가톨릭의과대학 방사선치료실

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연 세 암 센 타

추 성 실

온열요법이 암환자치료에 있어 온열요법 단독 또는 방사선치료나 일부 항암화학요법제와 병행할 때 그 효과가 상승되고 있음은 최근 잘 알려진 사실이다.

가톨릭의대부속 강남성모병원 방사선치료실에서는 온열요법의 동물실험과 더 나아가 임상응용을 목적으로 가정용 전자레인지를 개조하여 극초단파유도관을 제작, 부착시킴으로서, 실험 및 종양부위에 2,450 MHz 극초단파를 조사할 수 있는 장치를 제작하였다. 아울러 이 온열치료장치가 온열치료기로서의 적합성을 알아보기 위하여 본 실험을 실시하였다. 실험을 위한 phantom으로, 고기덩어리와 한천을 이용하였으며, 마우스하지에 발생시킨 Sarcom-180 고형종양을 또한 이용하여, 이 온열치료기의 전압변동에 따른 온도분포 변화를 측정하였다. 한편 실험동물종양에서는 종양조직내 온도가 주위 정상조직보다 1~3℃ 높은 것을 확인할 수 있었다.