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SUBMILLIMETER DIAMETER INTERSTITIAL MICROWAVE HYPERTHERMIA APPLICATORS: PRECLINICAL TESTING

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ABSTRACT

Interstitial hyperthermia applicators as small as 0.20 mm in diameter have been fabricated using ultraminiature coaxial cable. Animal studies show less local tissue trauma with equivalent heating to commercial 1.1 mm diameter applicators. Precise nonsurgical hyperthermia of deep-seated tumors may be achievable with these applicators.

INTRODUCTION

The therapeutic use of heat to treat cancer (hyperthermia) is becoming accepted as an adjuvant to radiotherapy in the treatment of locally advanced solid tumors. Clinical studies have shown that all viable regions of the tumor must be raised above a critical minimum temperature for effective therapy. Interstitial hyperthermia has an advantage over external methods in that there is better control over the temperature distribution, but its application has been limited, in part, by the trauma associated with large (1.1 mm diameter) applicators. This paper presents our work with submillimeter diameter interstitial applicators which may overcome some of these limitations.

MATERIALS AND METHODS

We have constructed applicators using ultraminiature 50 Ohm coaxial cables having diameters of 0.20, 0.33, and 0.58 mm using the conventional dipole design (1). As shown in Figure 1, there is a 2 mm long gap in the outer conductor located 3.5 cm from the tip, and a short between the two conductors at the tip. The length of ultraminiature cable in each applicator is limited to 16 cm due to the relatively high attenuation of this cable (Table 1). The transition from the submillimeter section of the applicator to the larger coaxial feed must be made with care because of the small size and the necessity to maintain a constant impedance to reduce the VSWR.

Clinical use of hyperthermia requires knowledge of the pattern of energy deposition (SAR, specific absorption rate, i.e., the rate of energy deposition per unit mass) produced by an applicator. We have used a miniature (3 mm diameter) implantable isotropic electric field probe developed at the Center for Devices and Radiological Health, FDA (2) for

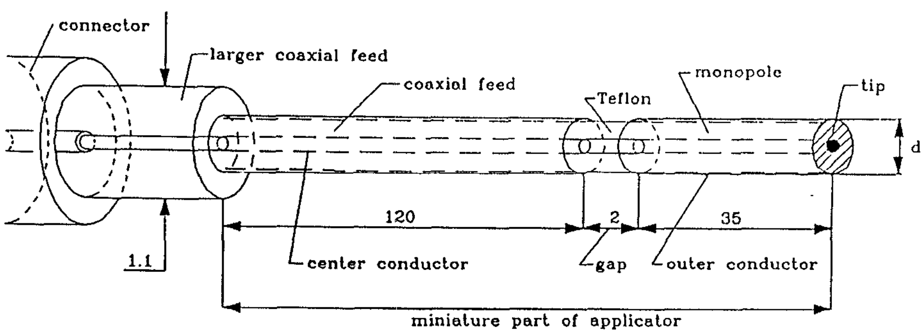

FIGURE 1. Details of the submillimeter microwave hyperthermia applicators (all dimensions in mm). The submillimeter coaxial section of the applicator has outer diameters of 0.20, 0.33, or 0.58 mm.

TABLE 1

Characteristics of Miniature Coaxial Cables

Designation	Outer Conductor Diameter (microns)	Outer Conductor Thickness (microns)	Center Conductor Diameter (microns)	Attenuation at 1 GHz (dB/m)
UT-8[1]	200	20	50	6.33
UT-13[1]	330	40	80	3.83
UT-20[1]	580	80	130	2.37
custom[2]	1100	160	250	1.07

[1]Micro-Coax Components, Inc., Collegeville, PA 19426
[2]New England Electric Wire Corporation, Lisbon, NH 03585

determining SAR. The active elements (three orthogonal dipoles) of this probe are approximately 2 mm in length, and centered 2.1 mm from the end of the probe. The measurements were made in a phantom having dielectric properties approximating those of muscle and other high water content tissues (3). A block diagram of the experimental arrangement used to determine SAR is shown in Figure 2.

Miniature female laboratory pigs weighing 25 to 30 kg were anesthetized and implanted with arrays of four applicators (2 cm by 2 cm square) in the liver and thigh. A custom computer-controlled hyperthermia system built at the University of Miami (4) was used for the animal studies. Microwave power at 915 MHz was connected to each applicator array through a four-channel splitter.

RESULTS

Figure 3 shows the iso-SAR contours which we have obtained for single applicators in Teflon catheters having the minimum diameter appropriate for each applicator. Data could not be taken closer to the applicator than the points marked with an "*", which were the maxima used for normalization. Figure 4 shows the iso-SAR contours for arrays of four applicators in Teflon catheters arranged on a 2 cm by 2 cm

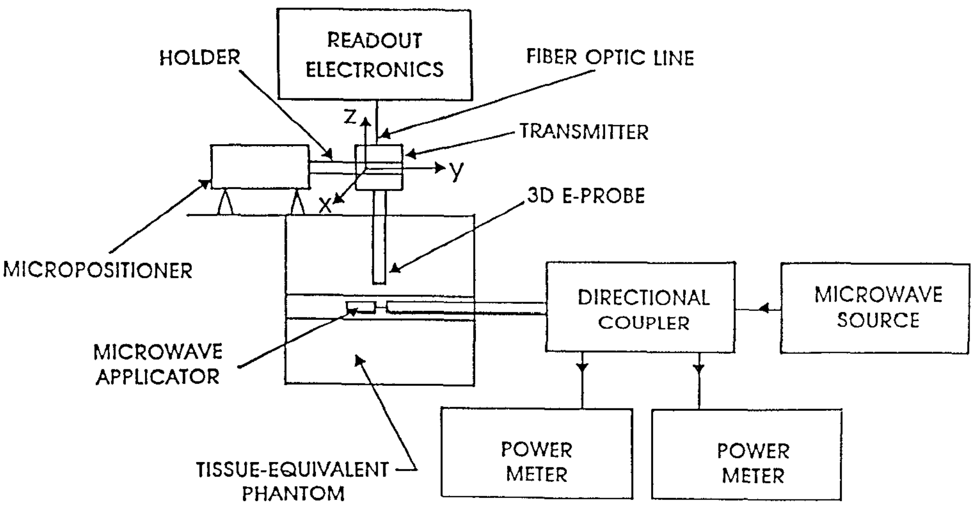

FIGURE 2. Block diagram of the measurement system.

square. The SAR for arrays was determined in a plane that is perpendicular to the applicators and passes through the gap in the outer conductor of each applicator.

Animal studies were made comparing arrays of 0.33 mm and 1.1 mm diameter applicators in both pig liver and thigh. Temperature tracings for these studies show the similar heating ability of both sizes of applicators. The liver, which is highly vascularized, produced profuse bleeding with the larger applicators, but not with the smaller.

DISCUSSION

The iso-SAR contours in Figures 3 and 4 suggest that, in tissue equivalent phantoms, the new submillimeter applicators produce heating patterns comparable to those of the larger commercial devices, which would be anticipated because they are similar in design. Animal studies suggest that the submillimeter applicators achieve heating equivalent to that produced by the larger devices.

We conclude that our submillimeter applicators show considerable promise for clinical application. Their placement in tissue produces less local tissue trauma, they produce heating patterns equivalent to those of larger devices currently available, and they appear to have sufficient ruggedness and power handling capability.

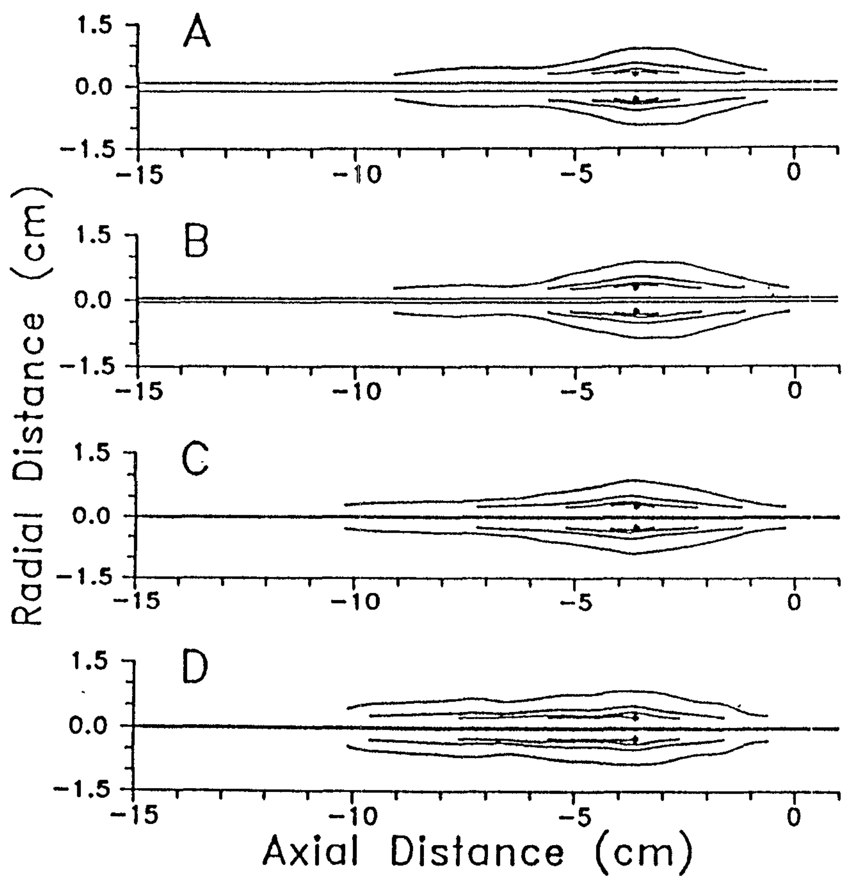

FIGURE 3. Iso-SAR contours for applicators in Teflon catheters. The outside of the catheter is represented by the two horizontal lines. The applicator tip is at "0", and the gap is located at approximately -3.5 cm. Contours are normalized relative to the maximum labeled "*". The contours progressing outward from the maximum represent 80, 60, 40, and 20 percent. A. Clini-Therm applicator (1.1 mm O.D.) in catheter having 1.7 mm O.D./0.26 mm wall. B. Applicator (0.58 mm O.D.) in catheter having 1.0 mm O.D./0.15 mm wall. C. Applicator (0.33 mm O.D.) in catheter having 0.69 mm O.D./0.15 mm wall. D. Applicator (0.20 mm O.D.) in catheter having 0.61 mm O.D./0.15 mm wall.

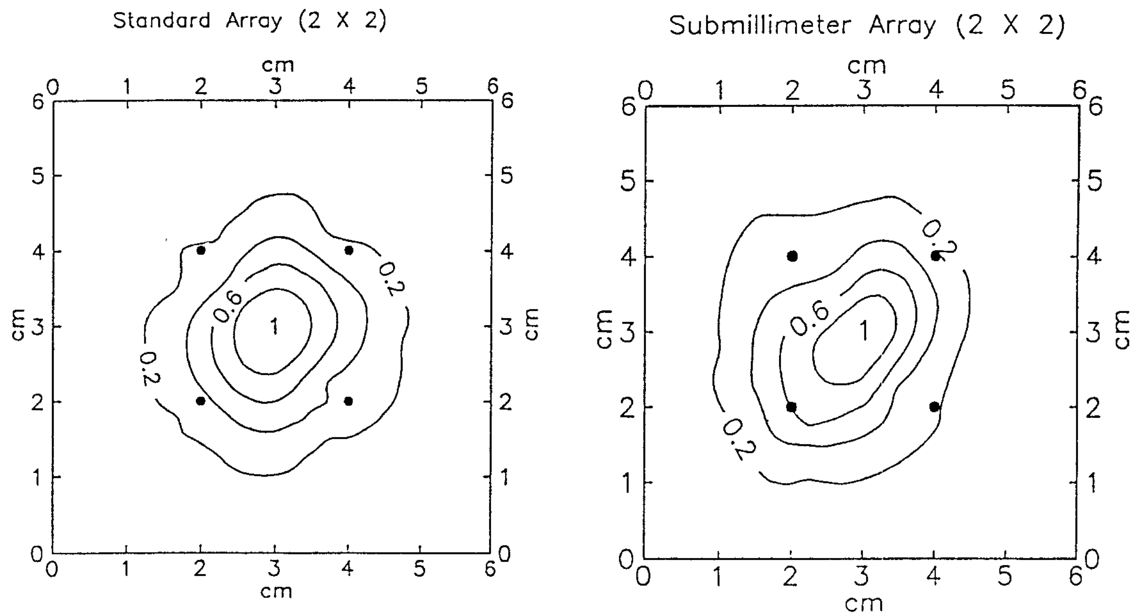

FIGURE 4. Iso-SAR contours for arrays of four applicators in Teflon catheters arranged on a 2 cm X 2 cm square. The four contours represent 80, 60, 40, and 20 percent of the maximum SAR which is located at "1". A. Clini-Therm applicator (1.1 mm O.D.). B. Submillimeter applicator (0.33 mm O.D.).

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