A BOLUSING TECHNIQUE FOR BATCH MICROWAVE IRRADIATION OF TUMORS IN THE FAR FIELD

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ABSTRACT

A technique of 2450 MHz microwave hyperthermia has been developed for the simultaneous irradiation of multiple mouse tumors in the far field. Superficial 1 cm tumors were exposed to microwaves by being drawn through the surface of a protective mouse shield, then encapsulated in a larger bolus of tissue equivalent material. This technique markedly improved tumor heating uniformity (to $\pm$ 0.15° C at 45° C). A replicable bolus shape was formed using expanded polystyrene molds. Placement of the tumor mold assemblies on an equipower surface of our anechoic range permitted the simultaneous irradiation of multiple mouse tumors.

Introduction

Hyperthermia, either used alone or in conjunction with ionizing radiation has been effective in treating certain experimental cancers.[1] The effectiveness of the treatment, in thermal killing of cancer cells, or in decreasing their resistance to ionizing radiation, is critically temperature dependent.[2] Below 42° C, heating may actually enhance malignant cell growth. Above 45° C, unacceptable thermal damage to normal tissues may result. Between these limits, cancer cells are killed, or made more x-radiation sensitive, in direct proportion to the temperature. Thus an ideal heating system for hyperthermal cancer therapy should be capable of producing highly uniform temperatures within a treatment volume.

In our laboratory, microwave heating has been investigated as a means of providing hyperthermia within superficial mouse tumors (C3H/HeJ). The design requirements for microwave heating were: (a) heating should be uniform to within $\pm$ 0.1° C throughout a 1 cm tumor; (b) heating should be localized to the tumor region; (c) the apparatus should be capable of administering the same hyperthermal treatment to a number of animal tumors simultaneously; (d) the heating method should be standardized and replicable. Furthermore, the heating should be independent of tumor size between 0.5 cm and 1.5 cm diameter, and the heating time required to achieve a specified temperature should be the same for each tumor.

Methods

For this study, a heating approach using far-field 2450 MHz irradiation was chosen. An anechoic chamber (8'x8'x8') was constructed where field measurements indicated a far field quite zone of 1 m^2. When shielded animals were placed in the chamber on a surface of equal power density, up to 12 animals could be irradiated simultaneously. A cross-section of the irradiation setup is shown in Fig. 1. Expanded polystyrene was used in fabricating all supports and pedestals.

Each animal was enclosed within a cylindrical metal shield, with its superficial flank tumor drawn through a slot aperature for exposure to the heating field (Fig. 2). Bare 1 cm tumors were difficult to heat, and the resultant internal tumor temperature profile was grossly non-uniform ($\pm$ 1° C at 40° C).[3] To achieve replicable and uniform tumor heating, independent of tumor size, each tumor was encapsulated in a spherical bolus of tissue equivalent material.[4] For a sphere of tissue-like material 4-5 cm in diameter, microwave heating is peaked at a central site, where temperature gradients are minimum.[5] By encapsulating the 1 cm tumor at this site, steady state temperature distributions generated by microwave heating were uniform to within $\pm$ 0.15° C at 45° C over the entire tumor volume.[6]

Figure 3 illustrates a two-piece bolus mold, constructed from low-loss expanded polystyrene. The mold technique is based on a similar procedure described by Guy,[4] and is utilized to standardize and replicate bolus geometry and to define tumor location. The mouse shield is shown in place in the lower mold half, with the tumor encapsulated within a 5 cm sphere. The bolus surrounds the tumor and partially envelopes the central sleeve region. To reduce moisture loss from the bolus, a thin plastic film is placed between it and the mold surface. The mold assemblies are placed at predetermined range locations, equispaced on a far field equipower surface (Fig. 1).

A 3 kW (PM) microwave source (Gerling Moore #4006) is used for heating. The source output is feedback-controlled to maintain the desired treatment temperature. The mold assemblies are spaced at least two wavelengths apart to minimize interactions. One mold assembly, containing bolus, but no animal, is used as a range calorimeter to feedback control the source. The feedback signal is provided by a minimally-perturbing temperature probe, placed at the tumor site in the bolus. The baseline temperature of the range is also feedback-controlled during heating.

Discussion

As currently developed, the microwave heating system is being used to study microwave hyperthermia of the model mouse carcinoma, alone and in combination with x-ray therapy. In future studies, the bolus technique will be applied to other model tumor systems in mice, and to normal and cancerous tissues in larger animals, with the view to eventual clinical applications to man.

References

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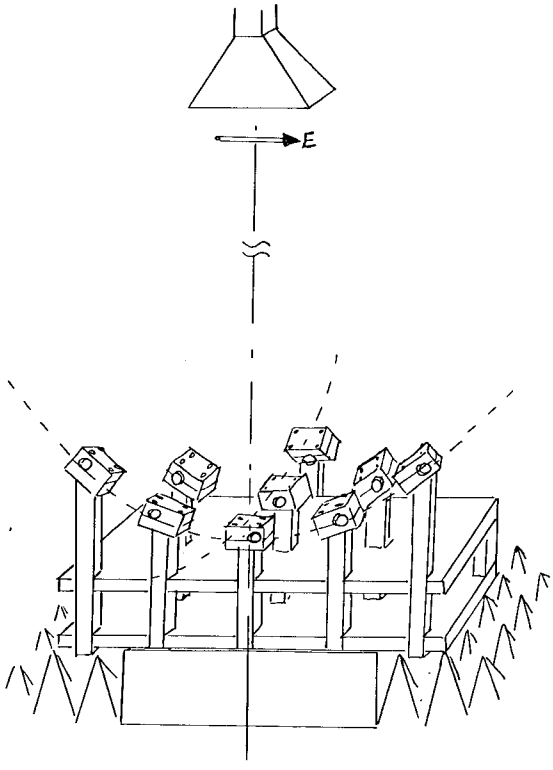

Figure 1. Mass-irradiation set-up. Mold assemblies we located on an equipower surface in the anechoic chamber. Cross-section through center of range.

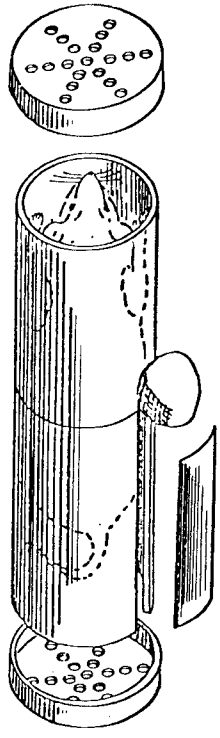

Figure 2. Cylindrical mouse shield, with tumor projecting through a slot aperture.

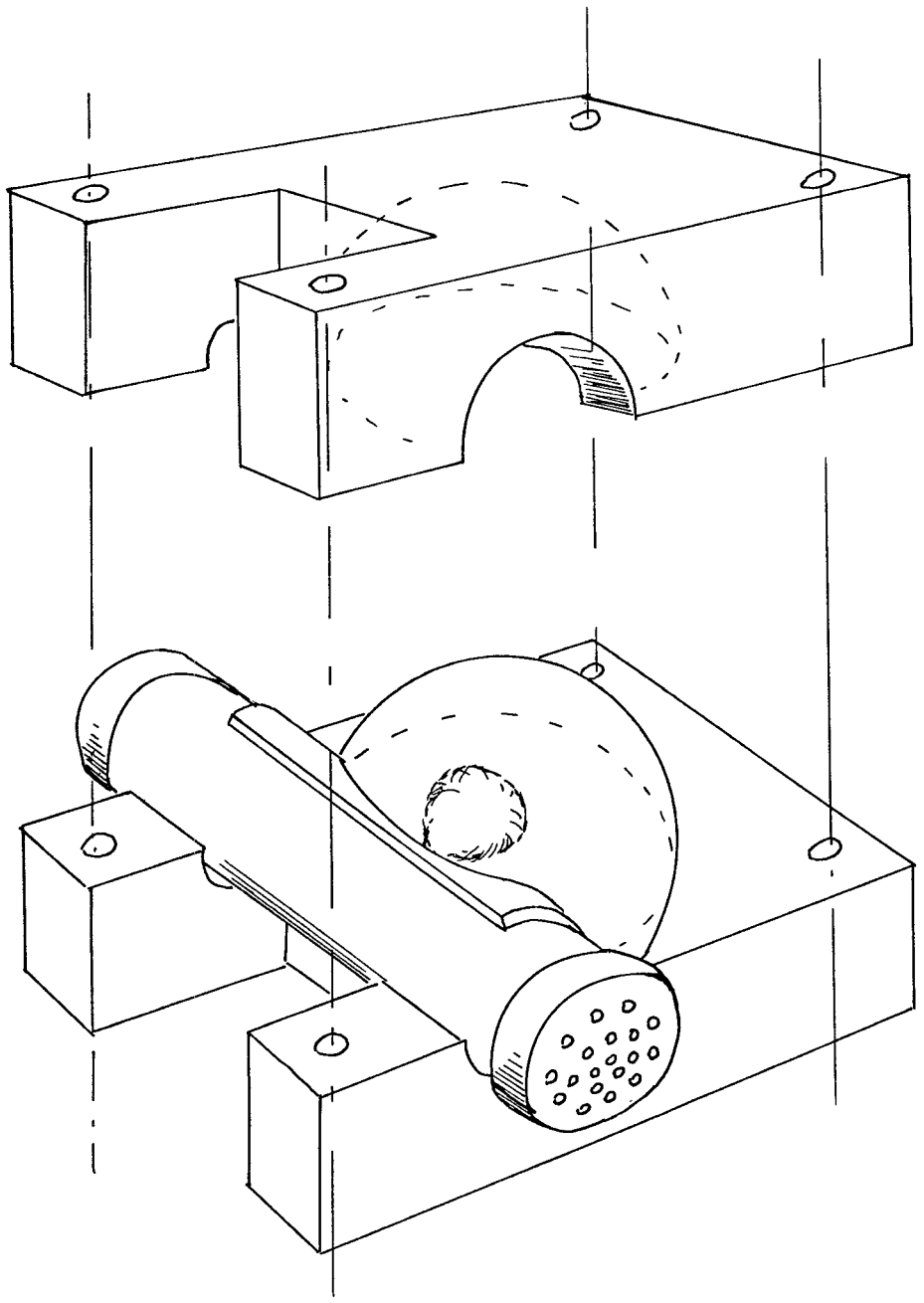

Figure 3. Two-piece mold assembly. Assembly bolts not shown.