Interstitial Antennas for Generating Asymmetric Heating Patterns in Microwave Ablation

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Microwave ablation (MWA) is a promising low-cost minimally invasive thermal cancer therapy that uses interstitial antennas operating at high power levels to heat tumors to cytotoxic temperatures. To date, numerous designs for MWA antennas have been proposed, most of which have focused on frequencies less than 2.5 GHz. However, a recent study has suggested that higher microwave frequencies are also capable of generating large ablation zones (H. Luyen, et al., IEEE Trans. Biomed. Eng., 61, 1702-1710, 2014). At higher microwave frequencies, direct electromagnetic heating as well as thermal diffusion are responsible for generating ablation zones with dimensions comparable to those produced with low-frequency microwaves (e.g. 915 MHz or 2.45 GHz). Using higher frequencies for MWA, however, allows for drastically reducing the length of MWA antennas, which can reduce the invasiveness of this potential cancer treatment. Here, we exploit this miniaturization feature and investigate novel antenna designs that provide capabilities which are not easy to achieve from low-frequency MWA systems.

Interstitial MWA antennas are typically implemented using coaxial cables that are structurally symmetric in the azimuthal direction. The resulting heating patterns are thus rotationally symmetric (in the absence of tissue anomalies that would perturb the SAR pattern) and only ideal for treating axially symmetrical tumors. These types of antennas must be placed in the center of the tumor to achieve a complete ablation. In many clinical situations, the tumor is asymmetrical in shape and/or the optimum ablation location (e.g. the center region of a tumor) may not be easily accessible. For example, access into the center of a tumor may be blocked by a vital organ or region of an organ that cannot be penetrated and only the periphery of the tumor may be accessible with the ablation antenna. In such situations, interstitial antennas that can generate ablation zones with unconventional or asymmetric shapes are highly desirable.

In this paper, we explore new interstitial dipole antenna designs for producing tilted and asymmetric heating patterns. The balanced nature of the design eliminates the need for using a balun and thus, reduces the thickness of antenna. The dipole arms are deployed into the tumor beyond the end of the feed line, in a manner similar to that used for RF ablation probes. The deployment angles are varied in simulations to achieve different heating patterns. Our investigations to date suggest that these types of antennas show promise for enabling greater customization of the shape of the ablation zone than what is currently possible.