ANALYSIS OF A FLOATING SLEEVE ANTENNA FOR LOCALIZED HEPATIC ABLATION

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Microwave ablation (MWA) is a promising technology for the treatment of liver tumors. MWA utilizes electromagnetic waves to heat tissue to high temperatures, thereby destroying all the cells in the heated region. The heated region ideally includes the tumor along with a 1 cm margin of normal hepatic tissue. This technology has been used successfully in both intra-operative and percutaneous approaches for primary hepatocellular carcinoma and hepatic metastasis of colorectal carcinoma. A persisting problem with the existing technology is the control of the region of microwave absorption and the heating distribution during interstitial MWA. The design of the antenna determines the shape of the energy deposition pattern and an improperly designed antenna can lead to significant power reflection and heating along the antenna.

We have designed, analyzed, and experimentally tested a novel interstitial antenna for hepatic microwave ablation. The antenna consists of a coaxial dipole antenna with a floating metal sleeve that is electrically isolated from the outer conductor of the coaxial feedline. The sleeve is used to prevent propagation of the EM wave along the outside of the coaxial feed and thereby reduce backward heating along the feedline. Simulations of the antenna suggest that this design achieves a highly localized SAR pattern that is independent of insertion depth and is well matched to normal liver tissue at 2.45 GHz. Experimental measurements of the input reflection coefficient of the antenna inserted into ex vivo liver tissue are in good agreement with the simulated results. Ex vivo liver ablation experiments demonstrate that the floating sleeve antenna achieves a highly localized ablated region in the liver.

The design process and optimized antenna design indicates that the length of the sleeve is critical to the localization of the SAR pattern. We examine the reasons for this and the importance of the electrical isolation of the sleeve from the outer conductor. We also examine the performance of the antenna when it is immersed in tissue exhibiting a range of dielectric properties. The liver is a fairly homogeneous medium but we expect some difference in the dielectric properties of the tumor into which the antenna is inserted, relative to the surrounding normal tissue. Preliminary work has also indicated changes in the complex permittivity with temperature and level of tissue desiccation. An ideal antenna design would maintain a favorable SAR pattern for a wide range of tissue permittivities.