Microwave Ablation: Surgical Perspective

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The Field Effect of Microwave Heating

Thermal destruction by microwaves has been used effectively for many years for ablation of both small liver metastases and primary lesions. Microwaves produce effective ablation without islands of viable cells in a rapid and reproducible fashion. The microwave region of the electromagnetic spectrum is well suited to such a role due to the efficient conversion of electromagnetic energy to heat. This translation of energy is a result of the strong interaction between polar molecules and microwaves that causes oscillation of molecules, which is expressed as heat.

Water is a highly polar molecule, abundant in both normal liver tissue and hepatic neoplasms; it is the interaction between the microwaves and water that is principally responsible for the rise in temperature. The interaction between water and the entire range of frequencies in the microwave bandwidth is particularly strong. It is no coincidence that the fastest form of heating foodstuffs in the domestic kitchen is the microwave oven, principally due to the interaction between water molecules and microwaves.

Another advantage of microwave ablation is the manner in which the heating occurs. Unlike the alternative ablative devices such as radiofrequency or cryotherapy, the passage of heat is not solely reliant on conduction. The fundamental reason why microwave energy is unique and efficient is that it is transmitted from a suitable applicator or probe as a “field” around its tip. Direct heating of water molecules occurs within the whole microwave field, not simply by conduction of heat from the surface of a hot probe. A whole spherical area, perhaps the size of a tennis ball, is heated simultaneously and uniformly within minutes. Heating is not reliant on conduction through the tissues. Cytotoxic increases in temperature are reached rapidly. Beyond the microwave field, however, heating of the adjacent tissue does occur by thermal conduction.

The distinction between conductive heating and direct field heating is important, as conduction through water-laden tissue is slow and inefficient, particularly when the effects of local blood flow act as a heat sink. The interaction between the microwave field and water molecules of the target tissue within that field occurs very rapidly; consequently, the temperature climbs quickly. Theoretically, microwave coagulation should be the most efficient method for the destruction of large liver tumors.

Until recently the production of large, predictable ablations with microwave devices has not been possible unless multiple insertions of a probe or needle were used, similar to radiofrequency ablation (RFA). This constraint has limited its use among liver surgeons and interventional radiologists for ablation of colorectal metastases and small primary hepatocellular carcinomas in cirrhotic patients. Currently, the treatment of larger tumors has been possible only by multiple placements of a microwave probe that produce overlapping
volumes of ablation. This is undesirable, as the technique requires highly skilled, accurate placements of the probe to avoid leaving islands of viable islands of cells in the target tumor. It also means that many patients will undergo multiple treatment sessions.

The Development of a New Microwave Applicator for Large Liver Tumor Ablation

Over the last decade a new form of microwave treatment applicator, the microwave endometrial ablation (MEA) applicator, has been developed by Microsulis Medical Ltd., UK in conjunction with scientists at the University of Bath, UK. The initial focus was in the field of gynecology. A microwave applicator was designed specifically to treat women with menorrhagia using an 8.5-mm-diameter antenna that was able to produce a heated microwave field from a generator delivering a frequency of 9.2 GHz. Microwave endometrial ablation now is an established method to destroy the endometrium. It has been successfully used to treat more than 30,000 patients worldwide and the safety and efficacy of this treatment has been extensively validated in randomized controlled trials (Fig. 17b.1) (1). The uniqueness of the applicator is its ability to transmit microwave energy via a coaxial cable with extremely efficient heating of tissue within its microwave field.

The data gained from the experiments into the microwave properties of tumor tissue and normal liver parenchyma have given physicists more knowledge of the electromagnetic properties of target tissues and how they change during treatment. Using this information, accurate computer models have been constructed to test the efficacy of novel applicator designs, thereby avoiding the need to “bench-test” every new probe. The models assess radiation of the microwave into the tissues and the degree of reflection that will occur.

Animal Experiments on Production of Large Ablation Volumes by Microwave Energy

Female pigs (body weight 45–50 kg) were anesthetized and underwent a laparotomy to allow good exposure of the liver. Once adequately exposed, the novel microwave applicators were inserted into the hepatic parenchyma and ablations were carried out at varying times (1 to 3 minutes) and power settings (45 to 250 W). The most remarkable finding was that the microwave equipment was able to produce large volume ablations (5 to 8 cm in diameter) quickly, and were spherical in nature. The results were reproducible, and there was a linear relationship between the size of burn and the power output for any given time (2,3). Thus, accurate treatment volumes could be calculated for any given tumor size. The animals tolerated the production of multiple liver ablations extremely well. A large, 7-cm liver ablation with a single insertion is seen in Figure 17b.2, produced by using the 6.4-mm probe, powered at 150 W, at a frequency of 2.45 GHz.

Clinical Studies with Large Ablations

Although microwave liver ablation has been used extensively in the Far East over the past 20 years to treat primary liver tumors in cir-