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A Review on Microwave Ablation Technique for Hepatocellular Carcinoma

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ABSTRACT
Thermal ablation is becoming most widely used techniques for treatment of benign and malignant tumors of different organs like the liver, lung, kidney and also the bone [1-5]. It is the best alternative for the candidates who cannot undergo the surgical resection. Ablation techniques have proven well even in case of treatment of solid tumors in organs such as breast, prostate, adrenal glands, pancreas and also the uterus [6-12]. Ablation followed by other techniques like chemotherapy and usage of nanoparticles in curing have proven to improve the treatment efficacy [13-19]. This paper reviews the advent and development of Microwave Ablation Technique. We provide an overview of physical and technical aspects of MWA. Microwave Ablation was first introduced in Far Eastern clinical practice in early 80's. In the initial stage it was having the issues of controllability of the emitted field, poor coagulation process [70]. With the time there have been a lot of improvements and technique has really grown well to tackle HCC.

Keywords – Thermal Ablation, HCC, Microwave Ablation, Tumor, Hepatocellular Carcinoma

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I. INTRODUCTION

Thermal ablation is the technique used for treatment of cancer in the patients who are not the surgical candidates. In here, the temperature would be raised above a lethal threshold about 50-60 degree Celsius through direct energy deposition, which eventually turns into heat within a limited and controlled range of action. Resection is still the favored treatment option for early-stage HCC in patients with well compensated cirrhosis, but thermal ablation techniques provide a valid non-surgical treatment alternative, thanks to their minimal invasiveness, excellent tolerability and safety profile, proven efficacy in local disease control, virtually unlimited repeatability and cost effectiveness [9, 10]

It used to be believed that ablation for tumors adjacent to large vessels, liver surface, biliary tree, or near to bowel should be avoided [20] for the concern of major complications (SIR classifications C–E)[21] or the incomplete coagulation. For tumors adjacent to large vessels, three major issues should be focused. First, large vessels close to the tumor could take the heat away to flowing blood and prevent complete ablation, which is known as heat-sink effects. This effect could cause a higher local tumor progression (LTP) rate [22–24]. Second, the heat might cause damage to surrounding vessels, decrease the supple of liver and even cause liver failure [25–27]. Third, some studies reported that an increase in intratumoral pressure during ablation could cause dislodgement and spread of cancer cells to the remote part of the liver through surrounding vessels [28–29]. Microwave (MW) ablation seemed to be a better choice than radiofrequency (RF) ablation in treating HCC adjacent to large vessels, for its advantages of a lower susceptibility to heat-sink effects (blood-vessel-mediated cooling), as well as the ability to achieve larger tumor volumes in shorter time [30]. Related studies have been published in those years.

II. TECHNIQUE

Microwave ablation is a technique used for killing cancer cells, it basically utilizes dielectric hysteresis to produce heat. Tissue destruction occurs when tissues are heated to lethal temperatures about 50-60 degree Celsius from an applied electromagnetic field, typically at 900–2500 MHz. Polar molecules in tissue (primarily H_2O) are forced to continuously realign with the oscillating electric field, increasing their kinetic energy and, hence, the temperature of the tissue which causes the necrosis.

Tissues with high content of water are most suitable for this type of treatment. Unlike Radiofrequency ablation which uses resistive heating method to heat the tissue up, in Microwave ablation the energy is being radiated into the tissue through an interstitial antenna which functions to couple the energy from the source point to the tissue which is being targeted for the process of necrosis. Microwaves are capable of propagating through and effectively heating many types of tissue, even those with low electrical conductivity, high impedance, or low thermal conductivity [31-37]

III. KEY COMPONENTS OF A MICROWAVE SYSTEM

The basic microwave system consists of three components: a generator, a power distribution system, and antennas. Due to shaft heating caused by reflected power, a cooling system is a crucial component of most microwave antennas. Power is generated using either magnetron or solid state sources. Microwave generator output can be controlled relatively independent of the tissue type; the impedance spikes or reduced power output characteristic of RF ablation in high impedance tissues are not encountered in microwave ablation. Generator frequencies are generally either 915 MHz or 2.45 GHz [38, 39, 40–47]

Distribution of electromagnetic energy from the generator to the antenna is most commonly accomplished through a coaxial transmission line. Coaxial cables have excellent propagation characteristics, but as cable diameter decreases, power loss (and associated cable heating) increases. Thus, there is a limit to how small and flexible the cables can be without resulting in dangerous cable heating [48]

Microwave antenna design is a balance of power efficiency, tissue heating pattern, and antenna diameter with design tradeoffs necessary to produce a specific desired result. The ablation zone size and shape produced by any antenna in live tissue depends on the antenna design, tissue type (taking into account the changes in the tissue properties during the ablation), thermal conduction from the active heating zone, and thermal sinks caused by nearby structures such as blood vessels.

IV. MWA FOR HEPATOCELLULAR CARCINOMA

The liver is a vascular solid organ with an abundance of large vessels creating the potential for heat sink effects. Microwaves appear to be more apt to overcome perfusion and large heat sinks than other heat based ablation modalities [49, 50-53]. Microwave energy has been shown to ablate tissue up to and around large hepatic vessels measuring up to 10 mm and creates larger zones of ablation in high perfusion areas [49, 52–53]. High perfusion rates in hepatic vessels greater than 3 mm limits the effectiveness of radiofrequency ablation, and has been shown to be an independent predictor of incomplete tumor destruction [54]. The decreased susceptibility to vascular cooling has been studied and confirmed in preclinical studies.

Clinically, even with early-generation microwave ablation systems, microwave ablation has already been shown in several studies to have equal effectiveness, safety and survival with shorter ablation times when compared to RF ablation for the treatment of small hepatocellular carcinomas [55, 56, 57].More recent studies with newer microwave systems have re-demonstrated the efficacy of microwave ablation in the liver [55, 58–62]. In addition, preclinical data has suggested that microwaves, particularly with the use of multiple applicators, may be effective in the treatment of larger tumors (> 3cm) [63-64, 65, 66]. Tumors over 3 cm have historically been problematic for radiofrequency ablation, with a significantly increased risk of local tumor progression [67–69]. However, the larger ablation zones possible with microwave ablation could potentially make these tumors more consistently treatable. From a practical standpoint, decreased time needed for microwave ablation translates to more efficient use of equipment and personnel and decreased time for patients under general anesthesia, which is routinely used for ablation.

V. CONCLUSION

Microwave tumor ablation is a rapidly growing modality already used to treat early-stage tumors and gaining attention in combination therapies. The predictions of the active heating zone and heating behavior within tissue will give out the better results of microwave ablations. Simulation studies with deeper understanding have led to reduced costs and improved efficiency. Computational and experimental studies have helped optimize the design of microwave antennas, generators and techniques, facilitating clinical translation and further adoption into clinics worldwide. The simultaneous development of modeling and validation will lead to better integration of patient-specific, interactive models that can change how ablation procedures are performed in the future leading to a better treatment and improved quality of patient's life.

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