



Microwave Radiation—Therapeutic Application for Cure of Liver Tumor

Simran Kaur¹, Surita Maini²

¹Faculty of Electrical Engineering, DAV Institute of Engineering & Technology, Jalandhar, Punjab, India

²Sant Longowal Institute of Engineering & Technology, Longowal, Punjab, India

Abstract: Hepatocellular Carcinoma (HCC) is a type of cancer arising from the liver. It is the fifth most common cancer in the world and the third cause of cancer-related death worldwide. The vast majority of HCC cases occur in developing countries, but incidence is on the rise in North America and Europe. HCC is characterized by cells covering both the internal and external parts of liver. Among different ablative therapies like ultrasound, radiofrequency (RF), cryoablation and microwaves, which are used to treat the cancer in liver tissue, the most promising method is Microwave Ablation (MWA). Effective MWA requires efficient interstitial antennas that destroy tumors providing minimal damage to the surrounding healthy tissue. To effectively treat deep-seated tumors, these antennas should produce a highly localized specific absorption rate pattern and be efficient radiators at different generator frequencies.

Keywords: Hepatocellular Carcinoma, Microwave Ablation, Interstitial Antenna

I. Introduction

The electromagnetic fields have a great influence on the behaviour of all the living systems. Microwaves occupy range in the EM spectrum is between frequencies of 300 MHz to 300 GHz with wavelengths of approximately 1 m to 1 mm. From several decades, hyperthermia has become major subject of interest in investigating the biological effects and applications of microwaves. Therapeutic applications of microwave ablation include treatment of liver tumors, lung tumors, throat cancer, and cardiac treatments [1-4]. In this application microwave energy is used to create localised dielectric heating (diathermy) resulting in controlled destruction of tissue. This paper investigates the potential for using high-frequency microwave energy which selectively kills tumorous cells while producing minimal damage to surrounding healthy tissue. As microwaves have shorter wavelengths the choice of frequency can benefit the application, for example large volume ablations can typically be made at 915 MHz and 2.45 GHz and use of higher frequencies in the range 5.8 GHz - 10 GHz can create shallow penetration of energy resulting in very precise ablations suitable for treatments such as ablation of the heart to treat arrhythmia, multiple small liver metastases [8]. Traditional microwave energy sources used in these procedures have poor efficiency, their large size requiring them to be located far from the patient. But recent studies represents that microwave heating can be used to be effective for the tumors and cardiac treatment.

II. Technology

The transport of thermal energy in biological tissue is a complex process. It involves multiple physical mechanisms including heat conduction, convection, radiation, metabolism heat generation, tissue water evaporation, condensation, etc. The water content in a tissue is about 40%–80% of its volume depending on the tissue type, which exhibits relaxation at 25 GHz at 37 C. The antennas developed for microwave ablation are minimally invasive and capable of delivering a large amount of electromagnetic power. These antennas are effective to treat deep-seated, non resectable hepatic tumors. The designs have focused largely on thin, coaxial-based interstitial antennas. When microwaves MW propagate through the biological materials, the energy of MW is absorbed by the materials.

Absorption in Human Subjects:

Biological effects depend on the field in the tissues, i.e., on the specific absorption rate (SAR). The specific absorption rate (SAR) is defined as the power dissipation rate normalized by material density [5].

$$SAR = \sigma / \rho E^2 \quad \text{W/kg} \dots\dots\dots(1)$$

where σ is the conductivity of the tissue (S/m), ρ is the density of the tissue (kg/m³), and E is the electric field (rms) (V/m). Human tissues differ in their permittivity [9], varying with frequency. The SAR takes a value proportional to the square of the electric field around the antennas and is equivalent to the heating source generated by the electric field in the tissue. The electrical properties of the tissue change because this treatment generates a high-temperature region in the tissue to coagulate the cancer cells. MWA is one of the thermal ablative technologies that heats tissue to a temperature high enough for all the phenomena to happen.

Pennes' Bioheat equation effectively describes how heat transfer occurs in biological tissue. [6-7]

$$\rho C \frac{\partial T}{\partial t} = k \nabla^2 T - \rho_b C_b F (T - T_b) + \rho \text{SAR} \dots \dots \dots (2)$$

The symbols in bioheat transfer equation are explained as:

T is the temperature (°C), t is the time (s), ρ is the tissue density (kg/m³), c is the specific heat capacity (J/kg K), k is the thermal conductivity (W/m K), ρ_b is the density of the blood (kg/m³), C_b is the specific heat capacity of the blood (J/kg K), T_b is the temperature of the blood (°C), and F is the blood flow rate (m³/kg s). Biological effects depend on the field in the tissues, i.e., on the specific absorption rate SAR (W/m³), defined as power deposited in a unit mass of tissue.

Human tissues differ in their permittivity, varying with frequency. Cancerous tissue, except when it becomes necrotic, is highly vascular and has increased water content. This finding directly accounts for an increase in the permittivity of tumors compared to that of host tissue. Typically, the permittivity is approximately 10%–30% greater for high water content tissues as skin, liver, muscle, and spleen. Progress in numerical methods and increased power of computers have made at least some niche applications finally appear feasible. The simulated models serve the quick and convenient evaluation for any device. These serve as a means of understanding the interaction between various phenomena that occur during ablation process.

III. Ablation Application

The main advantage of microwave ablation is the ability to create complete coagulative necrosis by heat regardless of the presence of fibrous tissue or a septum. Therefore, this therapy is effective for fibrous tumors and metastatic tumors that are usually resistant to ethanol ablation or chemobolization. Since tumors have unique properties of conductivity as a function of frequency. The overall purpose of these studies is to determine therapy measures of microwave frequencies which effectively destroy tumors at temperatures lower than frequencies that could damage human tissue. In hepatic cellular carcinoma microwave ablation thermally destroys the tumors by creating coagulation necrosis and protein denaturation. Hyperthermia is a technique used in the medical treatments of cancer and other medical therapy.

Tumors are heated to therapeutic temperatures (43°C–45°C) without overheating the surrounding normal tissue [7]. Key issues are heating, temperature measuring, and controlling the system. The basic principle of microwave hepatic ablation is to apply microwave power to the liver tissue through the microwave applicator—the antenna [8]. Antennas should produce a highly localized specific absorption rate pattern and be efficient radiators at different generator frequencies. The power of the MW is absorbed by the liver tissue and heats the tissue. Cancerous cells in the liver tissue are destroyed after the tissue is heated high enough for a long time. The ablation equipment includes a microwave generator and a family of electrodes. The microwave generator can deliver up to 50 W to destroy or ablate the tumor. A microwave generator emits an electromagnetic wave through the exposed, non insulated portion of the antenna.

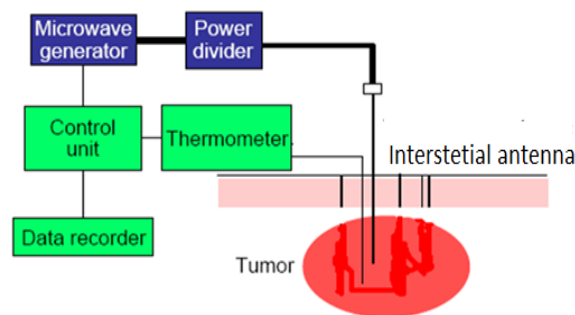


Figure. 1 MW interstitial antenna set up.

Electromagnetic microwaves agitate water molecules in the surrounding tissue, producing friction and heat, thus inducing cellular death via coagulation necrosis. The thermometer is attached to the antenna which indicates the internal temperature of the heated tissue. The operator can set the desired temperature. The ablation method comprises of heating each tumor to around 100 C for at least 6 min; the generator automatically adjusts the power to attain the proper temperature and displays delivered power, impedance, and temperature. This technique offers the use of Multiple Probes in the surgery. Multiple probe microwave ablation may allow for treatment of larger, more complex tumors as well as simultaneous treatment of multiple tumors. Multiple probe ablation may improve treatment of tumors near blood vessels. The main advantages of microwave technology include consistently higher intratumoral temperatures, larger tumor ablation volumes, faster ablation times, and an improved convection profile. This thermoablative technique enables local control of liver tumors without resection. Microwave ablation has promising potential in the treatment of primary and secondary liver disease.

IV. Conclusion

Microwave ablation offers a great advantage in clinical applications. The physical properties of microwave technology make it an ideally suited energy source for tumor ablation. Improved characterization of tissue properties and heat transfer mechanisms at elevated temperatures are required to improve models of high powered microwave ablation. Improvements in lesions produced will make this therapy more amenable for patient-specific treatment planning. All the applications of MW consist of an antenna applicator fed by means of coaxial cable, which passes through a catheter. Microwave power is easy to deliver through antenna and can provide safe subsurface heating of biological tissue. It can be preferentially deposited across interfaces of different kinds of tissue, with a fairly controllable pattern. One would expect the therapeutic uses of microwaves to increase in the coming years. This technology is still in its infancy, and future developments and clinical implementation will help improve the research in this field

V. References

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