

Microwave Coagulation Therapy Using Microwave Antenna

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Abstract: The purpose of this paper is to illustrate the microwave coagulation therapy (MCT) that can be used mainly for the treatment of hepatocellular carcinoma. In this treatment invasive technique are used in which thin microwave coaxial antenna is inserted into the tumor and the microwave energy heats up the tumor to produce the coagulated region including the cancer cells. We have to heat the cancer cells up to at least 60°C above which the cells are coagulated.

It is very difficult to estimate the properties of a certain antenna shape, due to complicated relationship between the geometry of the antenna & the electromagnetic fields. To evaluate the performance of any antenna, computer simulations based on various numerical techniques are used. Finite Element Method is an efficient technique used for performing analysis of complex structures allowing the flexibility in changing the shape of the antenna. This method consists of representing a given domain, however complex it may be by geometrically over which the approximation functions can be systematically derived. The Finite Element Method not only overcomes the shortcomings of the traditional analytical and numerical methods but it also endowed with the features of an effective computational technique. FEM models can provide users with quick, accurate solutions to multiple systems of differential equations.

Flexibility is the greatest advantage of finite element method with respect to the other traditional methods. In this method the subdivisions may consist of triangles, general quadrilaterals (of first order or higher orders) or their combinations with or without curved sides. These can be fitted very easily to the profile of any complex shaped domain. The grid can be made fine or coarse in different regions of the solution domain in a very flexible way as and when required. The solutions obtained by finite element method

using COMSOL Multiphysics, as compared with all numerical methods, are approximate, though any degree of accuracy can be achieved provided sufficient numbers of elements are used. In many practical problems, however, the desired accuracy can be achieved with few elements. As with all numerical methods, separate solution is required for each set of parameter of a problem.

Keywords: Hyperthermia, Applicator, SAR (specific absorption rate), temperature distribution.

1. Introduction

Hyperthermia is one of the most promising new multidisciplinary approaches to cancer therapy. The basic idea behind this treatment is to expose the body tissue at high temperature 43-45°C, killing the malignant cell and damaging proteins and structures within cell, hyperthermia may shrink tumors. A diagram of the fundamental components of a hyperthermia system is shown in Figure.1. Hyperthermia is still under study in clinical trial and is not widely available yet at clinical instructions. It is always used as a compliment to other type of cancer therapy such as radiation therapy and chemotherapy.

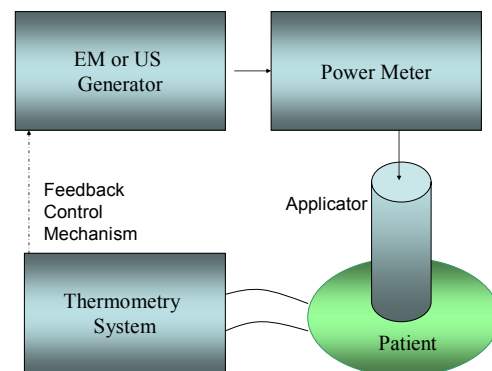


Figure.1 Fundamental element of representative hyperthermia system

Hyperthermia makes some cancer cell more sensitive to radiation or even damages other cancer cells that are insensitive to radiation. Hyperthermia can also enhance the effect of certain anticancer drugs. The combination of hyperthermic with these therapies has been conducted for many kinds of cancers, including sarcoma, melanoma, and cancer of the head and neck, brain, lung, esophagus, breast, rectum, liver appendix, cervix, and peritoneal lining (mesothelioma). Hyperthermia is not considered as an independently treatment against cancer because not all the studies made. Although many showed a significant in tumor size or an increased survival in patients receiving the combined treatment. During the last decade there has been significant progress in the method of heat delivery, temperature monitoring, and thermal dosimetry. Several method of hyperthermia currently study [1, 2, 3, 4, 5, 6, 7, 8, 9] are Local hyperthermia (external, intraluminal or endocavitary, interstitial) Regional hyperthermia (deep tissue, regional perfusion, continuous hyperthermia), Whole body hyperthermia. There are basically two techniques to treat tumor which are discussed below.

Non-invasive technique shown in Figure.2 is used where the tumor is located just bellow the skin (superficial), where non-invasive applicator is located just around or near the appropriate region. Invasive technique shown in Figure.3 is used where the tumor is located deep within the body, where invasive applicator is inserted inside the appropriate region. It allows the heating of tumor more effectively than non-invasive technique do. There are several ways to apply the heat to the tissue that is applicator which may use micro-waveguide, antenna, and patches etc. In the recent few decades, various types of medical applications of microwaves have widely been investigated and reported. In particular, minimally invasive microwave thermal therapies using thin applicators are of a great interest. They are interstitial microwave hyperthermia and microwave coagulation therapy [10] for medical treatment of tumor in soft tissues (liver, kidney, breast etc). The use of temperature to shrink or eliminate tumors has been known from many years, but only in the past three decades the means for accomplishing reasonably controlled heating have been available. The first period of intense research in hyperthermia occurred during the 1970s and 1980s, and in 1984, it was legally

adopted in the USA as a medical procedure, specifically recommended for locally recurrent tumors, and for primary cancer. After that success, at least in the USA, there was a decrease in research activity, primarily caused by the difficulty in obtaining reliable and uniform heating at deep tissue sites. In the late 1990s, there has been resurgence in hyperthermia interest, and new approaches and new design for the applicators were developed. Currently in USA and Japan significant progress in microwave hyperthermia is reported [11-15] for better results, hyperthermia is associated with ionizing radiation and chemotherapy. The thermal effects that occur when the human body is exposed to electromagnetic radiation in the microwave frequency range could be used in medicine to treat tumors through hyperthermia. The frequency of the electric field determines the rate at which energy is delivered to the tissue. The higher the frequency, the faster the wave will lose energy as it propagates through the tissue. This is a main factor in find out the operating frequency for the applicators. Heating by the exposure of microwaves (electromagnetic field) in the frequency range of (108 – 1011 Hz) is explained by the energy transferred to the exposed tissue, primarily via capacitive coupling, which causes vibration of polar particles, mainly the water molecules. Soft tissues have high water content, and more than that, tumorous tissue is especially hydrated and becomes the region that preferentially concentrates heat.

For the treatment of superficial tumor non-invasive applicators are used, while the internal tumor invasive applicators are used. The operating frequency usually is 2.450 GHz, which is one of the ISM (Industrial, Scientific, and Medical) dedicated frequencies.

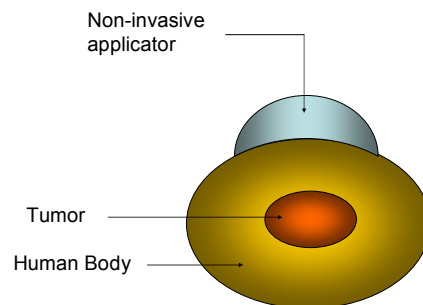


Figure.2 External Heating

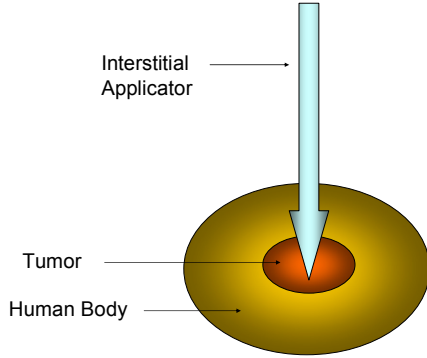


Figure.3 Internal Heating

Microwave radiation has a low penetration depth^[16] in anatomical tissues, on the order of 0.015 – 0.025 m, so external applicators will not deliver uniform thermal doses to tumor volumes. As a solution to that problem, local interstitial techniques have been developed that are proving to be safe and effective. These techniques employ implanted minimally invasive thin antennas for the delivery of local thermal doses; they are inserted through the skin, into a biocompatible catheter, under the guidance provided with an imaging monitoring procedure^[14-16]. The heat produced in the tissue is the specific absorption rate (SAR). The temperature is high nearby the applicator and decreases rapidly with the distance. For external applicators, surface overheating, and for interstitial applicators a non uniform temperature distribution occurs in the tumorous tissue volume. An attempt to solve this problem looks for adequate configurations of the applicator; the most popular solution was found to be the array antenna, with specific distribution of pins, either for external, or for interstitial application. In particular, invasive microwave thermal therapies using thin applicators (pins or needles) are of a great interest^[14, 15]. Their design (the number of the needles, dimensions and distances, working frequency, etc.) is very much related to the characteristics of the target region, means shape dimension electric property of the tumor and the surrounding tissue.

2. Design

Finite Element Method is an efficient technique used for performing analysis of complex structures allowing the flexibility in changing the shape of the antenna. This method consists of representing a given domain, however, complex it may be by geometrically

simple shapes over which the approximation functions can be systematically derived. A finite element model is developed to determine the absorbed power and the temperature distribution surrounding the single coaxial antenna. A single thin coaxial antenna used in this study is presented in Figure.4. The cable is short-circuited at the tip and a ring shaped slot, 1.5 mm wide, is cut at 6 mm distance from the tip. The radial dimensions of the pin, as much as the position and axial dimension of the slot were found to provide the optimal energetic coupling between the microwave source and the tissue. The antenna is inserted with the aid of a catheter (made of poly-tetra-flour-ethylene) PTFE, a biocompatible dielectric material), for both hygienic purposes and guidance; after the procedure, the catheter could be maintained inserted into the tissue for a later intervention. The physical properties of the materials involved in the model and specified were selected from literature^[15, 16, 18]. The electric properties are considered at the working frequency 2.45 GHz.

The COMSOL multiphysics user interface contains a set of CAD tool for geometry modeling in 1D, 2D, 3D, In addition it provide CAD import module for importing CAD data using all popular formats like SAT, CATIA V4, CATIA V5, Pro E, STEP etc. here figure5 show the different view of coaxial antenna designed in the CAD environment.

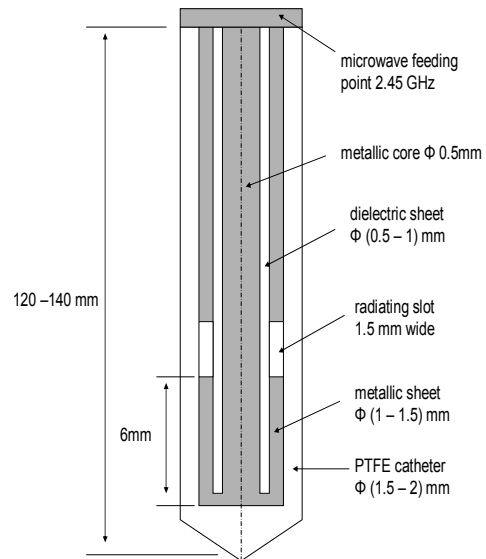


Figure.4 Single coaxial antenna with radiating slot

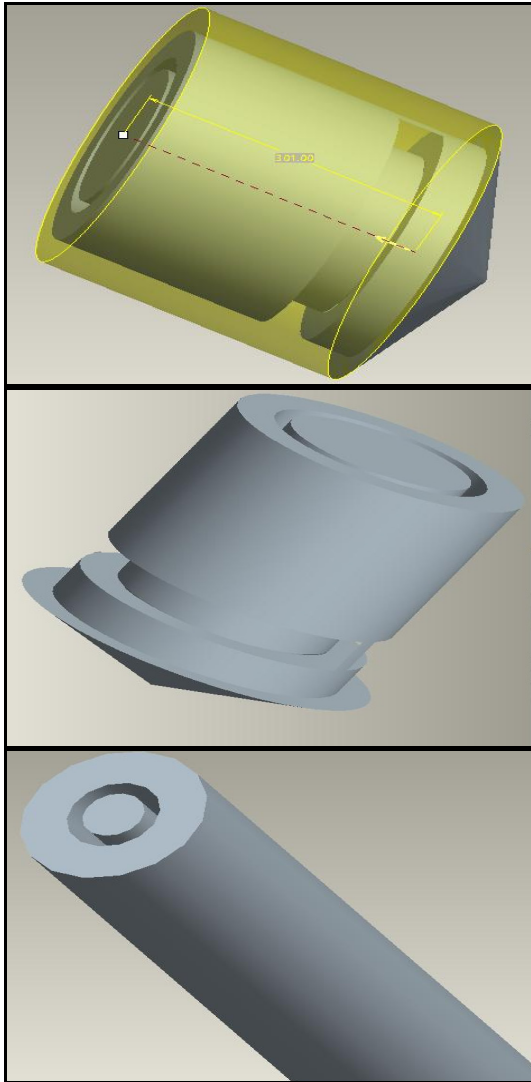


Figure.5 Different view of coaxial antenna designed into the CAD environment

3. Results

Finite Element Method using COMSOL Multiphysics is applied for the modeling of one thin coaxial antenna inserted into the tissue. The antenna described in “figure.4”, fed at 2.45 GHz. The tissue has the shape of a cylinder, coaxial with the antenna, with a radius of 30 mm, large enough to enclose the volume affected by the electromagnetic field source. The external surface of the cylinder acts as boundary for the computation domain. In the electromagnetic field problem, a low reflecting boundary condition is set on that surface, which means that the boundary does not disturb the electromagnetic

field distribution, while in the heat transfer problem the boundary is thermally isolated. The microwave source is set at the upper end of the coaxial cable and the power emitted is adjusted to 1W. The penetration depth of the absorbed power is found to be 1.55 mm (evaluated as the distance where SAR decreases at 1/e of its incident value) shown in figure.6.

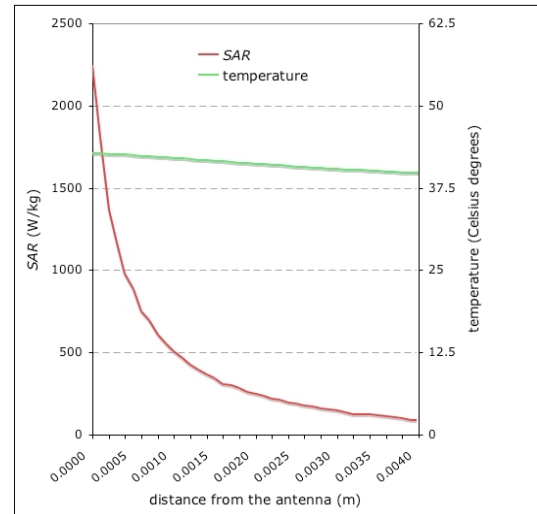


Figure.6 SAR and temperature decrease with the distance from the coaxial-slot antenna

4. Conclusion

This work presents the analysis of the thermal output produced by some microwave devices, with the objective to approach general criteria for the optimal design of minimally invasive hyperthermia microwave applicators used in medical therapy. The dimensions of the coaxial cable and the position of the radiating slot were first fixed through several trials, aiming at the most efficient energy transfer from the microwave source to the exposed tissue. The advantage of invasive probes is that the heat can be localized with higher precision, in a smaller and more deeply situated volume, than with external applicators. One disadvantage, of course, is that it could be uncomfortable for the patient. Treatment planning will require accurate characterization of the applicator deposition pattern and the tissue parameters, as well as a numerical technique to predict the resultant heating pattern. Still the promises for even a partially successful therapy for cancer spur the continued study of hyperthermia.

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