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A Review:" Cancer Cell Treatment Using Microwave Ablation Technique"

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Abstract— MWA is one of the new ablative technologies. It is not mature yet. Despite many promising advantages over other thermal ablative technologies, MWA still has many problems to be solved and technical challenges.

Keywords— MWA, SAR, RFA, MCT, HCC

I. INTRODUCTION

Hepatocellular carcinoma (HCC) is one of the majority common wicked tumors with an predictable 1,000,000 worldwide deaths every year. Constant or recurrent liver disease is the main cause of both morbidity and death in patients with HCC. The liver is the main site of outlying metastasis of colorectal cancer and practically half of the patients with colorectal cancer ultimately extend liver involvement during the route of their diseases. Nearly 150,000 original cases of colorectal cancer will be diagnosed in the US every year with 57,000 fatality. Amid men 40 to 79 years old, colorectal cancer is the second most important cause of cancer humanity. Primary and secondary malignant hepatic tumors are among the majority common tumors worldwide [1-4].Though the final control of this disease rests with the action of at-risk populations with vaccines for together hepatitis B and C, extirpation of tumor is the only potentially curative therapy for recognized cancers. Chemotherapy and radiation therapy are unproductive to treat liver tumors. Surgical resection is the gold normal for the treatment of patients with reputable isolated hepatic metastases with 40% 5 year and 26% 10 years survival. However, only about 25% patients are surgical candidates. In addition, the morbidity and humanity associated with surgical resection are comparatively high. For the majority patients, tumors may be too lock to the major hepatic blood vessels to be resected, or too a lot of tumor spots to be resected and the remained piece of the liver would not be sufficient to sustain normal liver functionality for the patients. Such patients cannot be surgical candidates. Patients without action will usually die in 1 to 5 years. Ablative treatments have in progress to become viable option methods to treat patients who cannot be treated by surgery. Such ablative treatments include cryoablation, radiofrequency ablation (RFA), microwave ablation (MWA) or also called microwave coagulation therapy (MCT), and ethanol ablation, etc. These ablation methods canbe performed in either open-hepatic operations or simply invasive percutaneous operations. Ablative treatments can take care of most nonsurgical candidate patients. These ablative treatments do not work evenly for all patients. Different ablation methods have different mechanisms, different rates of complication and reoccurrence. They are suitable for different patient groups.Among these ablative technologies, RFA and MWA are similar in many ways.Both of them use heat to treat and kill tumor tissues. RFA is much more mature than MWA. RFA has been used in clinical operations in the USA for years while MWA is still undergoing major improvements and is actively researched. Clinical trials for microwave liver ablation have been carried out in Asian countries.

II. MICROWAVE TISSUE ABLATION FUNDAMENTALS

The basic principle of microwave hepatic ablation is to apply microwave power to the liver tissue through the microwave applicator - the antenna. The power of the EM wave is absorbed by the liver tissue and heats the tissue. Liver tissue is destroyed after the tissue is heated to a high enough for a long enough time .Figure 1 shows basic devices to perform a MWA are a microwave generator, a microwave applicator—the antenna, and a section of flexible coaxial cable to connect the antenna to the microwave generator. Ultrasound scanners are often used in the MWA procedures to guide the placement of the applicator. Fiber-optic thermometers can be used to measure tissue temperature. MRI scanners can be used to examine lesion size after the procedures.

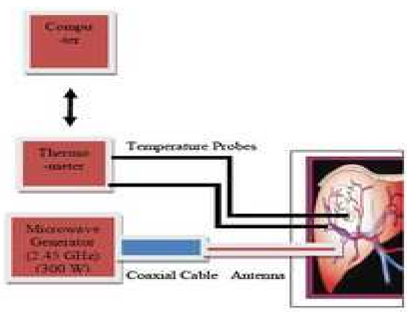

Figure 1: Schematic of experimental setup of microwave liver tissue ablation.

For a clinical procedure, the Luxtron fiber-optic thermometer and the temperature probes are not used.

In a clinical MWA procedure, position of the tumor is determined in advance with medical imaging devices, including MRI, CT or ultrasound devices. A MWA probe is placed into the tumor with an open surgery or a percutaneous procedure, guided by ultrasound or other medical imaging device. The probe is connected to the microwave power generator. Microwave power level and heating duration are selected in advance according to the shape and size of the tumor. Microwave power is then applied for the selected duration. A thermal lesion of predicted volume is created by the applied microwave heat to cover the entire tumor with 1 cm margin. The MWA probe is then safely retrieved. Before the clinical procedure is finished entirely, imaging devices can be used to verify the lesion size and shape. The ultimate goal of ablation technology, including MWA, is to kill the liver tumor while preserving healthy liver tissue effectively. In order to achieve the goal, an ablation method needs to:

- **Kill the liver tumor completely and effectively**

- MWA needs to create a thermal lesion large enough to enclose tumors of large sizes with about 1 cm margin.
- MWA needs to be able to overcome the heat sink effect of large blood vessels and kill tumors right next to such blood vessels

- **Minimize damage to healthy liver tissue and liver function**
- The thermal lesion created by MWA should be spherical in shape because liver tumors are generally spherical in shape.
- The thermal lesion should cover the tumor only and completely in order to reduce the thermal damage to adjacent normal liver tissues.
- MWA should selectively heat tumor tissue only instead of heating both tumor and normal tissues.
- MWA procedure should be easy to control to generate thermal lesions of desired sizes.

- **Easy, fast and less costly procedures**
- MWA procedures should be easy to perform
- MWA procedures, devices and probes should be cost effective
- MWA procedures should be performed quickly in order to reduce operational
- The ultimate goal of ablation technology, including MWA, is to kill the liver tumor while preserving healthy liver tissue effectively.

- **Disadvantages**
- MWA is less controllable on lesion size
- Detrimental backward heating

III. PROBLEMS AND CHALLENGES OF CURRENT MWA TECHNOLOGIES

MWA is one of the new ablative technologies. It is not mature yet. Clinical trials of MWA were mainly carried out in Asia. Researches on MWA are now going on. Despite many promising advantages over other thermal ablative technologies, MWA still has many problems to be solved and technical challenges.

- Lesion size limitation

In clinical trials or in-vivo experiments, a single MWA probe can only create thermal lesions of limited sizes in one pass [5, 6]. A common lesion size is 3.5 cm × 2.5 cm × 2.5 cm with 60 W and 120 to 300 s power application. The goal of an ablation procedure to treat liver tumor is to create a lesion covering the entire tumor with a 1 cm margin. For even a middle size tumor of 2 cm × 2 cm × 2 cm, a thermal lesion size of 4 cm × 4 cm × 4 cm is required to safely cover the entire tumor. Current MWA probes are apparently not powerful enough for such a requirement. Tumors in human liver could be in sizes up to 10 cm in diameter. Tumors are usually spherical shaped, except the ones close to the liver surface. RFA is able to create lesions of up to 7 cm in diameter with multiple RFA probe configurations. [7].

- Detrimental backwards heating

Detrimental backward heating is one of the major problems for MWA, especially for percutaneous treatments. The backward heating problem refers to the undesired heating that occurs along the coaxial feed line of the antenna. This detrimental heating causes damage to the liver outside the desired treatment region and can lead to burning of the skin during percutaneous treatment. This was the reason why Seki had to limit clinical trials to 60 W and 120 s in order to reduce the risk of skin burn. There are three potential causes of detrimental heating along the coaxial feed line. The 'tail' seen in many of the specific absorption rate (SAR) patterns computed from simulations of MWA antennas is attributed to this current flow.

- Control of lesion generation

Clinical treatment with MWA needs to control the lesion generation accurately in order to ensure destroying tumor tissue and minimizing damage to the normal liver tissue. Current MWA technology cannot provide such managed control over the MWA procedure because of the inhomogeneous liver tissue mechanical structure and lack of knowledge about the tissue thermal responses at higher temperature.

- Unknown tissue physical changes

The tissue physical responses to MWA at high temperature are not well understood. MWA can heat tissue to much high temperatures than RFA. At high temperatures, tissue undergoes many physical changes, including loss of tissue water, changes of the tissue dielectric properties, thermal properties and other physical properties because of changes in temperature and in tissue water content, protein denaturalization, tissue charring, etc. All of such physical responses of tissue affect the MWA procedure.

- Computer simulation

RFA is a much more mature technology. Computer simulations for RFA have been achieved with satisfactory accuracy. Due to the lack of knowledge about tissue physical responses for MWA, complete computer simulation of MWA is not achievable. Computer simulation is very necessary to design and optimize the MWA antennas. Computer simulation also helps to optimize the MWA procedure by predicting the lesion size, shape versus power level and duration. Without a good computer simulation at reasonable accuracy, such optimizations have been done through unreliable experimental trials.

IV. LITERATURE REVIEW

Cancer is a disease caused by an uncontrolled division of abnormal cells in a part of the body. It is a major cause of death, and its incidence is increasing every day. Various methods and protocols used which include chemotherapy, radiology, surgical removal of the tumor, etc. But these methods have many side effects that make patients feel unbearable pain and inflict deep anxiety. Over the past decades, there is a struggle to discover new techniques to fight against cancer. Hyperthermia is an old therapy of treatment that gives a new hope and which when combined with engineering techniques proves one of the best cancer treatment options. This paper reviews the relevant information for the combination of various engineering techniques with hyperthermia that are well organized according to the methods used e.g. Ultrasonic Hyperthermia; external Radio-Frequency Devices; Hyperthermic perfusion; Frequency Enhancers; apply heating to the target site using a catheter; Microwave hyperthermia; injection of super paramagnetic and magnetic nanoparticles [1].

In recent years, various types of medical applications of microwaves have widely been investigated and reported. Among them, microwave thermal therapy is one of the useful applications and is modality for cancer treatment. In this treatment, there are several schemes of microwave heating. The authors have been studying thin coaxial antenna for intra cavitary microwave heating aiming at the treatment of bile duct carcinoma. In this treatment, an endoscope is first inserted into the duodenum and a long and flexible coaxial antenna is then inserted into the forceps channel of the endoscope, which is used to insert the tool for surgical treatment. Finally, the antenna is guided to the bile duct through the papilla of Vater, which is located in the duodenum, and is inserted in the bile duct. Up to now, the heating characteristics of the antenna are investigated by numerical simulation, experiment using tissue-equivalent phantom and extracted organs. In this study, the authors have an experience on animal experiment using a swine. In the experiment, temperature rises around the antenna inserted into the bile duct were measured. From the results of this experiment, cooling effect by blood circulation was cleared [2].

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 least60°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 [3].

There are many perceived advantages of microwave ablation have driven researchers to develop innovative antennas to effectively treat deep-seated, non-resectable hepatic tumors. In this paper a coaxial antenna with a miniaturized sleeve choke has been discussed for microwave interstitial ablation therapy, in order to reduce backward heating effects irrespective of the insertion depth into the tissue. Two dimensional Finite Element Method (FEM) is used to simulate and measure the results of miniaturized sleeve choke antenna. This paper emphasizes the importance of factors that can affect simulation accuracy, which include mesh resolution, surface heating and reflection coefficient. Quarter wavelength choke effectiveness has been discussed by comparing it with the unchoked antenna with same dimensions [4].

Microwave thermal therapy is one of the modalities for cancer treatment. There are several schemes of microwave heating. The authors have been studying thin coaxial antenna for intracavitary microwave heating aiming at the treatment of bile duct carcinoma. Up to now, the heating characteristics of the antenna are investigated by numerical simulation and experiment for finding a possibility of the treatment. In this study, in order to consider practical situations of the treatment, heating characteristics of the antenna inserted into a metallic stent is evaluated by numerical simulations. Moreover, the relation between coagulation size of the tissue and the radiation power from the antenna is investigated experimentally. It must be considered, when the input power of the antenna is high (around several tens of watts). From these investigations, some useful results for practical treatments were found [5]

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Microwave coagulation therapy (MCT) has been used for the treatment of small hepatocellular carcinoma. In the treatment a thin microwave antenna is inserted into the tumor, and the microwave energy heats up the tumor to produce a 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. Previously, the antenna for MCT has been developed only by experiment and numerical analysis has not been conducted. In this paper, we describe the numerical analysis of the antenna for MCT. During the MCT treatment, the medium properties of the tissue change because the characteristics of the tissue change as the temperature rises. Therefore we should consider this point when analyzing the heating performance of the antenna [6].

Microwave thermal therapy is one of the modalities for cancer treatment. There are several schemes of microwave heating. The authors have been studying thin Coaxial Quarter Conductor Antennas (CQCA) for intracavitary microwave heating aiming at the treatment of hepatic cancer. Experimental protocol was composed by a radiation microwave power system and a thermometry system. We apply the microwave power during experiments was 10W, 20W, 30W, 40W, 50W, 60W, 70W and 80W which we set the maximum temperature control at 90°C for all case Experiment, Thermal sensors were placed next to the antenna at 1mm, a large number of experiments on porcine liver are carried out, the temperature distribution within the porcine liver are measured , for cases of different injected microwave power. Experiment for finding a possibility of the treatment. In this study, in order to consider practical situations of the treatment, heating characteristics of the antenna inserted into sample tissue. Moreover, the relation between coagulation size of the tissue, the radiation power from the antenna and the volume of lesion which the hepatic cancer was successful hepatic ablation. From these investigations, some useful results for practical treatments were found [7].

V. RESEARCH METHODOLOGY

In hyperthermic oncology, cancer is treated by applying localized heating to the tumor tissue, often in combination with chemotherapy or radiotherapy. Some of the challenges associated with the selective heating of deep-seated tumors without damaging surrounding tissue are: • Control of heating power and spatial distribution • Design and placement of temperature sensors Among possible heating techniques, RF and microwave heating have attracted much attention from clinical researchers. Microwave coagulation therapy is one such technique where a thin microwave antenna is inserted into the tumor. The microwaves heat up the tumor, producing a coagulated region where the cancer cells are killed.

VI. LIMITATIONS

The fact remains that there are no widely-available microwave systems for clinical use. This has hampered the study of microwaves for tumor ablation and resulted in many speculations about its efficacy without a great deal of scientific data to stand on. Commercial and academic development is ongoing to create microwave ablation systems that are less invasive and easier to use so that the promises of microwave energy for tumor ablation can be finally realized in the clinic.

VII. CONCLUSION

Computer simulation is very necessary to design and optimize the MWA antennas. Computer simulation also helps to optimize the MWA procedure by predicting the lesion size, shape versus power level and duration. Without a good computer simulation at reasonable accuracy, such optimizations have been done through unreliable experimental trials.

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