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Ablation Options For Treatment of HCC - MWA and RFA

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Abstract: Hepatocellular carcinoma (HCC) is the fifth most common malignancy in the world. Although it occurs predominantly in Asia and Africa, its incidence is rising in western countries where hepatitis C infection is common. Thermal destruction has been used effectively for many years for ablation of both small liver metastases and primary lesions (HCC). RFA and MWA are similar in many ways. Both of them use heat to treat and kill tumor tissues. 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. The prime goal of ablation technology is to kill the liver tumor while preserving the healthy liver tissue effectively. A study of microwave ablation and radiofrequency ablation, are summarized in this paper. The authors has been studying these techniques since long and concluded that further studies are necessary to evaluate its future role as local therapy for liver tumors as number of challenges must be overcome before ablation techniques can be considered a standard treatment for cancer. These include the development of new devices, techniques and the standardization of treatment protocols.

Keywords: HCC, radiofrequency ablation, microwave ablation Introduction

I. Introduction

The use of RF/microwaves in therapeutic medicine has increased dramatically since the last few years to treat tumors, cancer, arrhythmias, tachycardia, benign prostatic hyperplasia. Hepatocellular carcinoma (HCC) is one of the most common malignant tumors with an estimated 1,000,000 worldwide deaths per year. Primary and secondary malignant hepatic tumors are among the most common tumors worldwide [1-4]. Chemotherapy and radiation therapy are ineffective to treat liver tumors. Surgical resection is the gold standard for the treatment of patients with HCC, but in most of the patients, tumors may be too close to the major hepatic blood vessels, cannot be surgically removed, or too many tumor spots to be removed, which is again a big difficulty. Hence such patients cannot be surgically treated. Patients without treatment will usually die in 1 to 5 years. Ablative treatments have become viable alternative methods to treat patients with HCC which cannot be treated surgically. Radiofrequency and microwave ablation are relative new techniques to treat HCC. It is also being considered for tumors of the lungs and breast. The ultimate goal of ablation technology is to kill the liver tumor while preserving healthy liver tissue effectively.

RFA uses radio-frequency current, usually around 500 kHz to deposit energy over a sizeable region to heat up tissue. The voltage applied is approximately ~100 V, with applied power up to 200 W. RFA works by converting radiofrequency waves into heat through ionic vibration. The ionic friction generates the heat within the tissue only, leading to coagulation necrosis and cell death. The higher the current, the more vigorous is the motion of ions and higher temperature is reached over a certain time. The RFA probe is introduced transcutaneously, in a minimally invasive fashion, into the tumor. The goal of radiofrequency ablation is to achieve local temperatures to the targeted tissue, generally, thermal damage of the cells begins at 42°C; and when the temperature increases above 60°C, intracellular proteins are denatured, the lipid bilayer melts, and irreversible cell death occurs [5]. The ability to efficiently and predictably create an ablation is based on the energy balance between the heat conduction of localized radiofrequency energy and the heat convection from the circulation of blood, lymph, or extra and intracellular fluid [6]. The basic principle of microwave ablation (MWA) is to apply microwave power to the liver tissue through the microwave antenna. A microwave generator produces microwaves, typically around 2.45 GHz, with 60 W power. Interstitial antenna is inserted into the liver tissue, guided by ultrasound or other medical imaging device. The microwave power absorbed by the liver, heats the tissue above 60°C. A typical treatment cycle takes 60 s, which produces a lesion of about 2 cm diameter approximately. Treatment is repeated typically three times a week, until the entire tumor is ablated. Although MWA is a novel therapy that has several theoretical advantages over RFA like larger lesion zone, higher temperatures, and the ability for ablation with multi probes. Currently MWA is in clinical use in a number of Asian centers [7, 8]. Recently, advances in antenna design have led to a new MWA system in which power feedback is markedly reduced, allowing for longer times of application, greater power deposition, and larger ablation lesion sizes.

II. Techniques

A. Radiofrequency Ablation

There are different manufacturers employing various strategies to obtain larger ablation zones [9]. There are currently three companies in the USA who manufacture commercially radiofrequency tumor ablation probes, accompanying generators. These are Rita Medical (Irvine, CA) which uses temperature-controlled RF ablation, whereas Radionics (Burlington, MA) and RadioTherapeutics (Sunnyvale, CA) use impedance-controlled RF ablation. There is another one in Europe i.e. Celon. Figure 1. Shows the probes currently in clinical use.

In impedance-controlled mode, power is slowly increased and shut down once impedance rises above a certain level. Because impedance rise is due to charring and gas formation. In temperature-controlled mode some of the modern ablation probes have thermocouples embedded in it as shown in Fig.1(b) the thermocouple measures tip temperatures back to the generator. In temperature-controlled mode, usually the average tip temperature (i.e. the average of all measured tip temperatures) is controlled to be kept at a certain set temperature. The set temperature usually is between 95 °C and 100 °C.

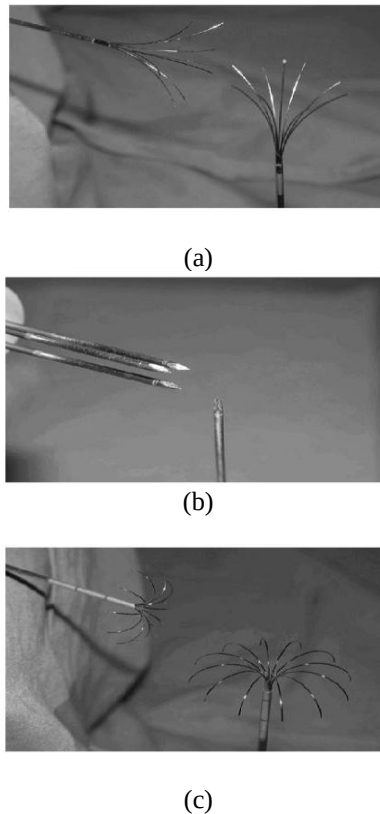


Figure 1. (a) Starburst XL probe (RITA, CA) (b) Cool-Tip probe (Radionics, MA) (c) LeVein probe (RadioTherapeutics, CA).

The survival rates of RF ablation after Five-year treatment are around 40%. A recent study showed local recurrence rates of around 40% [10], which is the result shows incomplete tumor ablation. Especially, when the tumor regions are next to blood vessels that act as a heat sink, which is responsible for recurrences observed [11]. Fig.2 shows a RF lesion created next to two large vessels (see arrows). The blood vessels caused a significant deflection of the lesions due to the cooling.

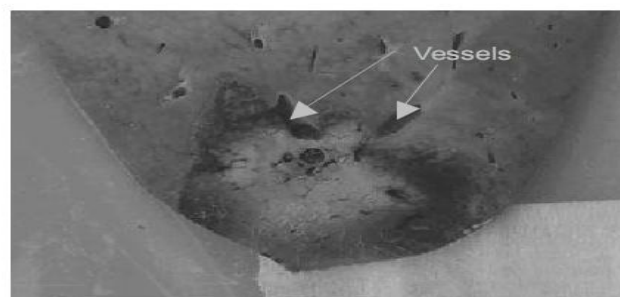


Figure 2. Blood vessels result in lesion deflection.

B. Microwave Ablation

Many different antennas designs have been proposed, optimized and verified. Coaxial-based antennas are extremely important for MWA application because of their low cost and small dimensions. Coaxial antennas differ in many ways: the allowed power level, thermal lesion size, lesion shape, antenna dimension etc. Detrimental backward heating is one of the major problems for MWA, refers to the undesired heating that occurs along the coaxial feedline of the antenna. This detrimental backward heating causes damage to the liver outside the desired treatment region which may lead to burning of the skin during percutaneous treatment. Different antennas have different tolerances to minimize backward heating. Several types of coaxial-based antennas, including the coaxial slot antenna [12], coaxial dipole antenna [13], coaxial monopole antenna [14], coaxial cap-choke antennas [15], and others, have been designed for MWA are shown in Fig. 3. Many researchers are doing effort to develop the less invasive interstitial antennas for microwave ablation for treating the liver cancer that are capable of producing highly localized patterns of electromagnetic power deposition in tissue.

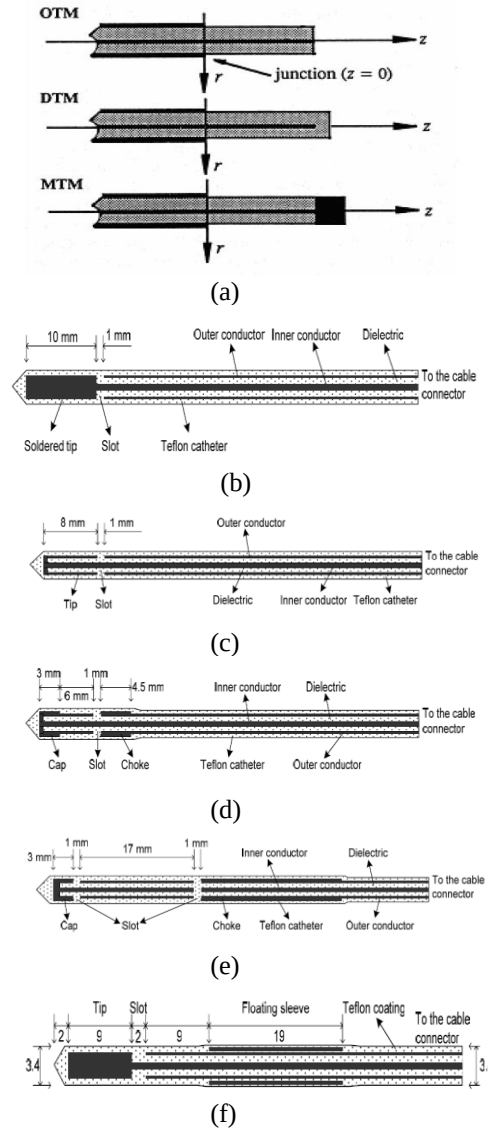


Figure 3.(a)Three basic configurations of monopole coaxial antennas Open-tip monopole (OTM), dielectric-tip monopole, metal-tip monopole (MTM). (b) Schematic of the dipole antenna (c)Schematic of the slot coaxial antenna (d)Schematic of the cap-choke antenna (e) Schematic of the double slot cap-choke antenna (f) schematic of the floating sleeve antenna.

III. Discussion

Although RFA has become an acceptable alternative treatment modality to treat HCC, but the researchers has to concentrate on its major shortcomings like, limited lesion size, inability to use multiple probes, insufficient temperatures, especially close to large blood vessels and insufficient interoperative imaging modalities. Moreover the results obtained from RFA were quite heterogeneous, and were successful only for smaller tumors with low

failure and complication rate. Studies have shown that lesions produced from RFA increases rapidly in size during the initial period of power application, but the rate of increase decreases rapidly as the resistance rises at the electrode-tissue interface and the current flowing through it falls.[16,17]. All thermal ablation technologies deliver heat energy to the targeted tissue by some sort of applicators and destroy tissue by heating.

MWA is one of the new promising ablative technologies because it is not mature enough yet. The clinical trials of MWA were mainly carried out in Asia and the researches on MWA are still going on. Despite many promising advantages over other RFA, MWA also has many problems and technical challenges to be solved, like lesion size limitation, detrimental backwards heating and control of lesion generation etc. Moreover the response of the tissue to MWA at high temperature is not well understood because tissues undergo many physical change i.e. loss of tissue water, change of dielectric properties of the tissue, thermal properties etc. MWA can heat tumor at high temperatures, capable of effective and controlled heating of large tissue volumes more than RFA and all of such physical responses of tissue affect the MWA.

Due to the lack of knowledge about tissue physical responses for MWA as discussed above, the complete computer simulation of MWA is not achievable. The computer simulation is very necessary to design and optimize the MWA antennas. Without a proper computer simulation at reasonable accuracy, the optimizations have not been possible before the experimental trials. This technology is still in its infancy, and future developments, computer simulations and clinical implementation will help improve the care of patients with cancer.

IV. Conclusion

Both RFA and MWA have anticipated a promising treatment modality to treat HCC that these can eventually replace surgical resection. It is expected that MWA will become more popular device in near future as it will mature. There seems to be little need to increase the lesion size in RFA.

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