NUMERICAL ANALYSIS ON BIPOLAR HEPATIC RADIO-FREQUENCY ABLATION

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INTRODUCTION

Hepatic radio-frequency ablation is an important surgical operation that deliver electrical energy of 460~550 kHz into liver tissue by using specified medical device [1]. Ablation probes are inserted percutaneously into tissues where tumors exist. Then electrical energy is delivered through the probes and the electrical energy turn into the thermal energy and heat the tissue to over 45-50 ℃ which cause cell necrosis and get rid of the tumors. It is very important to estimate the effective necrosis range as correctly as possible. Numerical analysis for the bipolar RFA is proposed to do this estimation in this study.

METHODS

The shape of ablation electrode was considered as a straight rod. Ablation electrode consists of the conducting tip and shaft. In this simulation the length of the conducting tip was assumed to be 3 cm, and the diameter to be 2 mm. And the shafts were assumed to be adiabatic. The liver model is a cubic shape having the dimensions of 10 cm × 10 cm × 7 cm.

Heat transfer in the liver tissue is governed by the following heat conduction equation

$$\rho c \frac{\partial T}{\partial t} = \nabla \cdot k \nabla T + \vec{E} \cdot \vec{J} - Q_{ex}$$

where ρ is density, c is heat capacity, k is thermal conductivity, $\vec{J}$ is current density vector, $\vec{E}$ is electric field intensity vector, and Q_{ex} is the metabolic heat source term. We assumed the metabolic heat source term is insignificantly small so that it was ignored.

The surface temperature in the liver model was assumed to be constant at 27℃. For the simplicity, we calculated only the half of the model by using the symmetry condition. AC current of 2000mAh was used for the simulation.

CFD-ACE(U) TM Ver. 2002 (CFD Research Corporation, 215 Wynn Drive, Huntsville, AL 35805) was used for the computation.

RESULTS AND DISCUSSION

The maximum temperature was 101.4℃, and the effective necrosis range, which is in the temperature range of above 60℃, was about 5 cm in length (Figure 1). High temperature regions above 80℃ were near the conducting tips, however, the isothermal surface of 60℃ covers the center part of the liver between the two electrodes.

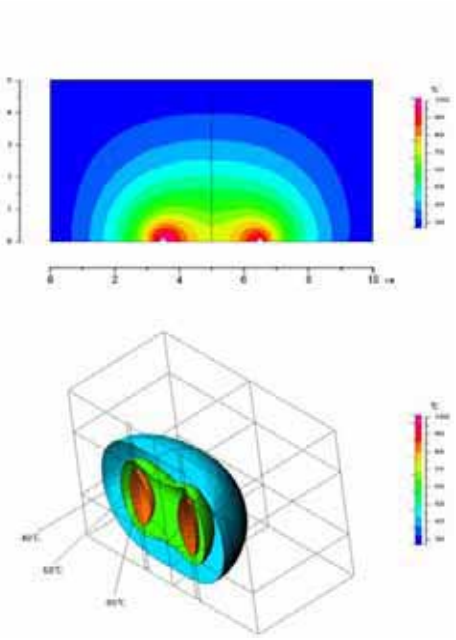

Figure 1: Isothermal surfaces (40℃, 60℃, 80℃).

In Lee et al. the inhomogeneity of liver tissue may cause the complicate electrical, thermal phenomena [2]. In addition, the blood flows in the liver obviously interfere during the RFA treatment. Also the temperature dependent properties of liver such as thermal conductivity, tissue heat capacity, tissue electrical conductivity and so on must be considered in the future work.

CONCLUSIONS

We conducted a three-dimensional numerical analysis on the bipolar hepatic RFA. As a result, we could get a reasonable necrosis range. Though there are significant limitations, this study still shows that the numerical method can be a useful tool for estimation of the effective necrosis range and diagnosis for the RFA treatment in near future.

REFERENCES

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