

CONFORMAL RF ABLATION TO REDUCE “DEAD REGION” WITH ADJUVANT INJECTION OF MAGNETIC MICRO/NANO PARTICLES: FEASIBILITY STUDY

Zhong-Shan Deng¹, Jing Liu¹, Ji-Ren Zhang²

¹Cryogenics Lab, P. O. Box 2711, Technical Institute of Physics and Chemistry,
Chinese Academy of Sciences, Beijing 100080, China

²Department of Oncology, Zhujiang Hospital, Southern Medical University,
Guangzhou, Guangdong 510282, China

INTRODUCTION

Radiofrequency (RF) ablation is a minimally invasive technique for tumor treatment. Intended benefits of oncological RF ablation include the availability of tumor treatment in nonsurgical candidate, minimal risk to patient, reduced morbidity and shorter recovery period compared with those after conventional surgery, and the potential for treatment on an outpatient basis. RF ablation, by producing heat energy that raises the temperature of the target tissue to a degree sufficient to cause thermally mediated coagulation necrosis, has been shown to be remarkably effective for thermal ablation of small tumors. Although RF hyperthermia has been successful in ablating small tumors, further optimization of the ablation technique is required to induce the larger volumes of coagulation that are necessary to treat larger tumors. In addition, due to the extremely irregular shape of tumor in clinics, the conventional RF ablation technique is hard to produce a conformal lesion to exactly enwrap the tumor as could as possible. This may lead to “dead region” within the area between RF probes and thus a failed treatment. To obtain a conformal treatment of complex tumor, strategies to flexibly control the size and shape of the ablated zone are desired.

It is well known that for a given total RF power output, the power deposition at each point in space is strongly dependent on the local electrical conductivity. Along this direction, it has been demonstrated that altering electrical conductivity of tissue through saline injection prior to or during RF ablation can increase RF tissue coagulation volume [1]. In our recent work, it was further suggested that magnetic micro/nano particles with high electrical conductivity can also be used as effective adjuvants to enhance the efficacy of RF ablation [2]. Consequently, it is possible to adjust RF tissue heating and

coagulation area by introducing materials with high electrical conductivity into the tissues before or during RF application, and thus to obtain conformal treatment of tumor.

Based on the above consideration, the feasibility of conformal RF ablation with adjuvant injection of magnetic micro/nano particles is demonstrated through numerical simulation in this study. It is indicated that alteration of tissue conductivity can be flexibly used to enable desired energy deposition in biological tissues, and thus conveniently controlling the size and shape of RF induced coagulation in tissues by injecting micro/nano particles with specific volume and concentration distributions. The results suggest that the present method will likely be used as an adjuvant therapy of RF ablation to achieve clinical benefit.

METHODS

Figure 1 gives the schematic illustration of computation domain and RF hyperthermia configuration used in this study. The tissue temperature responses to RF ablation are theoretically predictable on the basis of well-defined variables of electrical field equation and bioheat transfer equation. Readers are referred to [2] for details about the corresponding electrical field and heat transfer equations, and referred to [3] for details about the numerical algorithm, which are omitted here for brevity.

RESULTS AND DISCUSSION

Figure 2 and Figure 3 show the temperature distribution of tissue for the cases of no adjuvant injection and magnetic micro/nano particle injection. Clearly, there exists “dead region” between RF probes (Figure 2(a) and Figure 3(a)),

where the tissue temperature is hard to reach the threshold temperature for tissue necrosis. And injecting magnetic micro/nano particles into the area between RF probes can effectively eliminate such “dead region” (Figure 2(b) and Figure 3(b)).

Due to the irregular shape of tumor, the conventional RF ablation technique is hard to produce conformal treatment in clinics. To resolve this problem, strategies to flexibly control the size and shape of the ablated zone are desired. The results shown in Figure 4 indicate that adjuvant injection of micro/nano particles with high electrical conductivity during RF ablation can effectively realize such objects. Further results and detailed description will be presented at the conference.

ACKNOWLEDGMENTS

This work was partially supported by the National Natural Science Foundation of China and the Initial Funding for the Gainer of Dean Scholarship of CAS.

REFERENCES

[1] Lobo, S. M., Afzal, K. S., Ahmed, K., Kruskal, J. B., Lenkinski, R. E. and Goldberg, S. N., 2004, “Radiofrequency ablation: modeling the enhanced temperature response to adjuvant NaCl pretreatment,” *Radiology*, **230**, pp. 175-182.
 [2] Deng Z.-S., and Liu J., 2006, “Study on the enhancement of RF ablation by introducing adjuvants of saline solution or magnetic micro/nano particles,” ASME Summer Bioengineering Conference, Amelia Island Plantation, Amelia Island, FL, USA.
 [3] Deng, Z. S., and Liu, J., 2002, “Monte Carlo method to solve multidimensional bioheat transfer problem,” *Numerical Heat Transfer, Part B*, **42**, pp. 543-567.

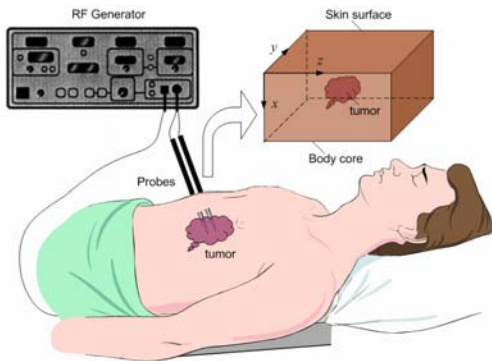
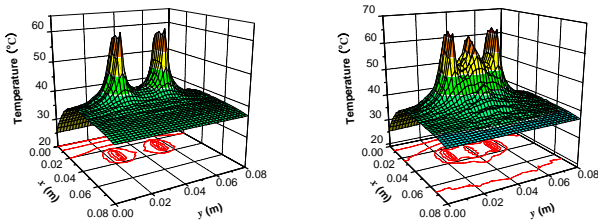
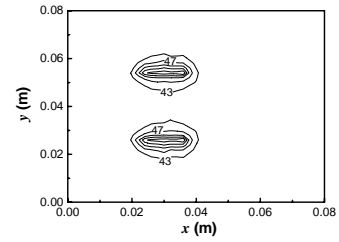


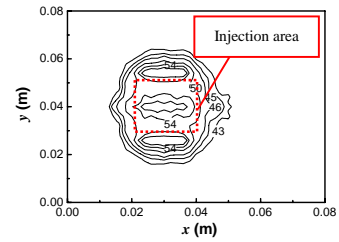
Figure 1. Schematic illustration of computation domain and RF hyperthermia configuration (not to scale)



(a) case of no adjuvant injection (b) case of adjuvant injection
Figure 2. Temperature distributions at t=2000s, z=0.04 m

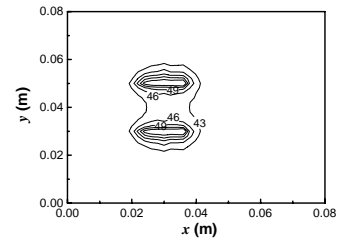


(a) case of no adjuvant injection

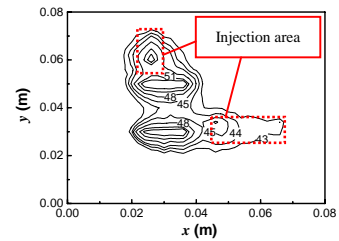


(b) case of adjuvant injection

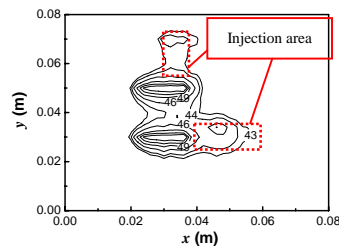
Figure 3. Temperature distributions at t=2000s, z=0.04 m



(a) case of no adjuvant injection



(b) case of adjuvant injection



(c) case of adjuvant injection

Figure 4. Temperature distributions at t=2000s, z=0.04 m