NUMERICAL MODELING OF INSERTED MICROWAVE HEATING PROBE IN POLYMER LOADED DRUG FOR CERVICAL CANCER TREATMENT

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ABSTRACT

This paper presents the results of computational study of inserted microwave heating probe into anticancer loaded polymer for localized hyperthermia and chemotherapeutic effect on cervical cancer. Finite element models of electromagnetic waves, heat transfer and mass transport concepts was used to simulate the temperature changes and drug release from the probe/polymer system to the surrounding environment that mimics the cervical cancer/healthy tissue. The predicted temperature ranges and released anticancer drug concentrations in abnormal tissue (cervical cancer cells) are shown to be in the range in which the combination of localized drug delivery and hyperthermia can a synergistically improve the therapeutic effects on cervical cancer. The implications of the results are also discussed for the design of implantable devices for localized chemotherapy and hyperthermia.

INTRODUCTION

Cervical cancer is the second most common cancer in women worldwide and is the most frequent cancer in many developing countries. Every year, 470.000 new cases of cervical cancer are diagnosed worldwide, and about half of the afflicted women will die. Although cervical screening has dramatically reduced the incidence of this disease in the developed world, it is still estimated that there will be 5.000 deaths from cervical cancer in the U.S. per year. In areas of the world where most women do not have access to regular gynecological care and screening, cervical cancer is second only to breast cancer as a cancer related cause of death. Cervical cancer discovered to be linked with Human PapillomaVirus which is transmitted through sexual intercourse, in most cases the male is a career of the papilloma virus that infects and generates in females. Despite the risks of the HPV virus both males and females are are hardly aware of the virus and the risks it carries.

MODELING

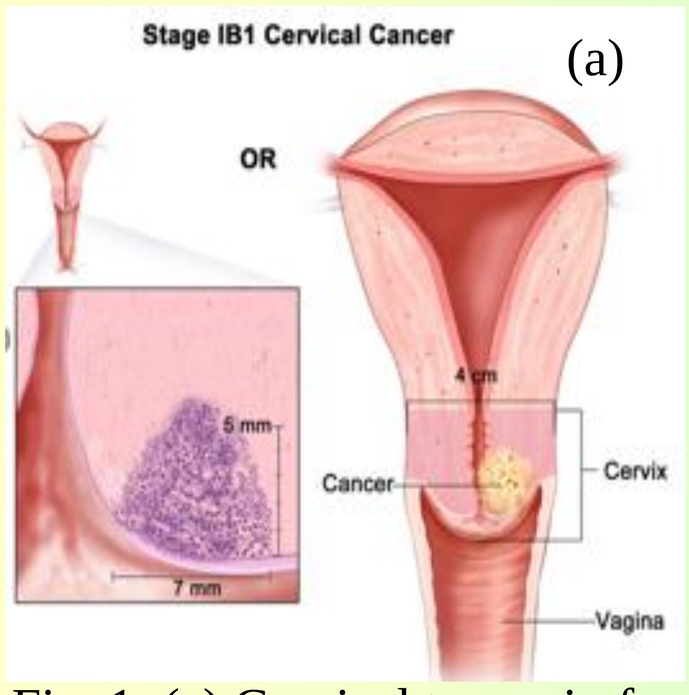
I. Hyperthermia Modeling

$$\nabla \times \left(\left(\varepsilon' - \frac{j\sigma_{el}}{\omega \varepsilon_0} \right)^{-1} \nabla \times \overrightarrow{H_\varphi} \right) - \mu_r k_0^2 \overrightarrow{H_\varphi} = 0 \qquad (1)$$

$$\rho C \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + \rho_b C_b \omega_b (T_b - T) + Q_{met} + Q_{gen} \qquad (2a)$$

$$Q_{gen} = \frac{1}{2} \sigma \left| \vec{E} \right|^2 \qquad (2b)$$

$$\Omega(t) = \ln\left(\frac{C(0)}{C(t)}\right) = \int_0^t A\, e^{\frac{-\Delta E}{RT(t)}}\, dt \qquad (3)$$



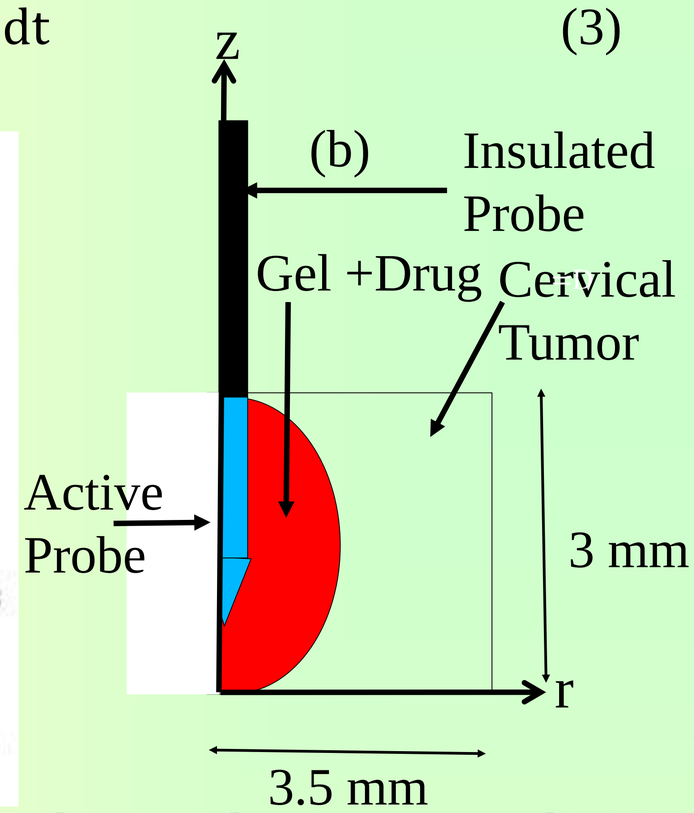


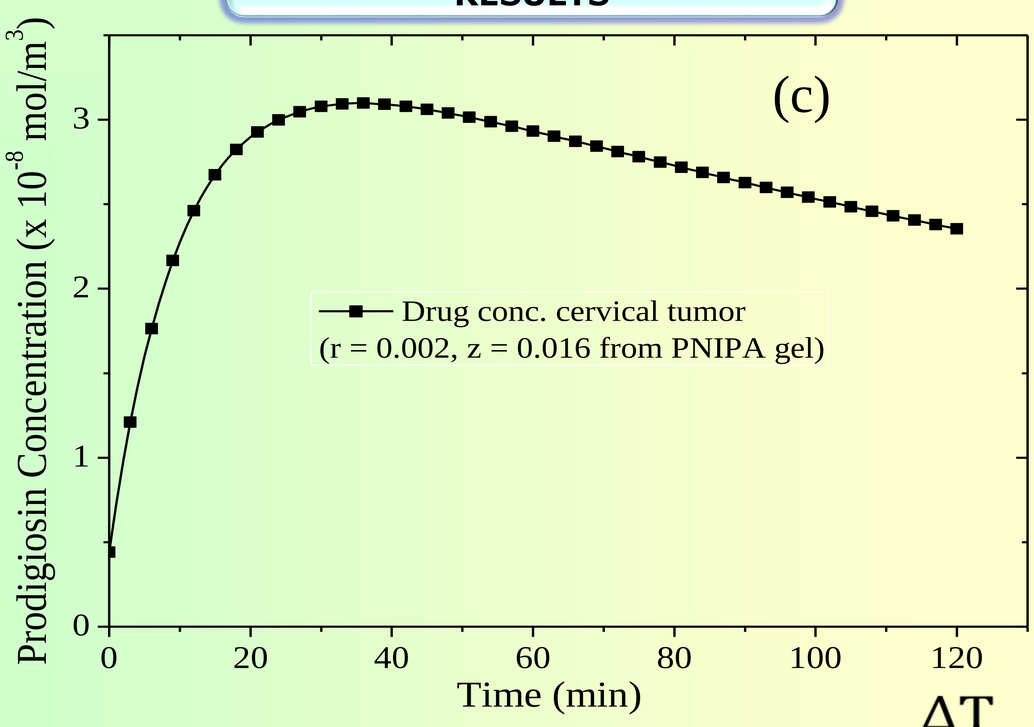
Fig. 1: (a) Cervical tumor in female reproductive organ, (b) 2D Model for FEM ,(c) Drug released in tumor, (d) Temperature distribution in PNIPA gel and cervical tumor, (e) Fractional thermal damage in tumor

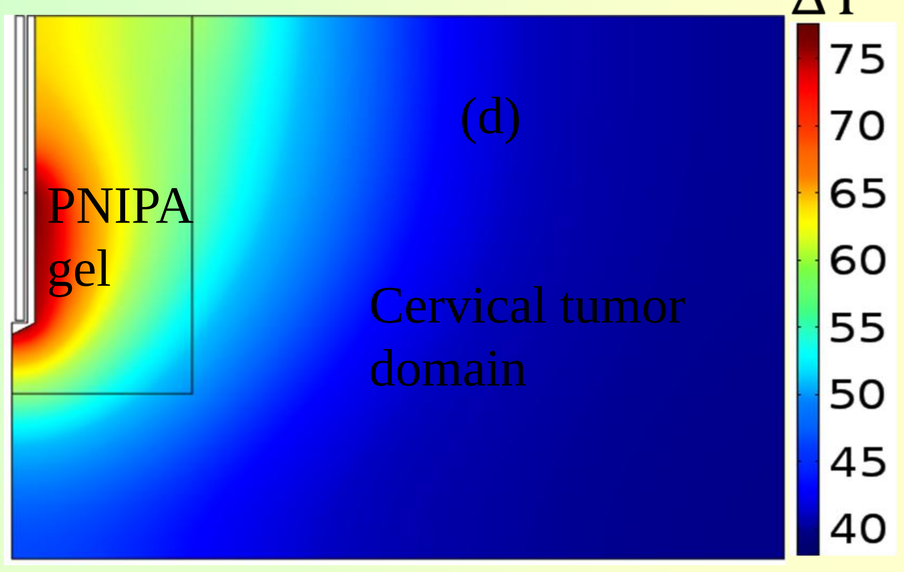
II. Modeling of Drug Release

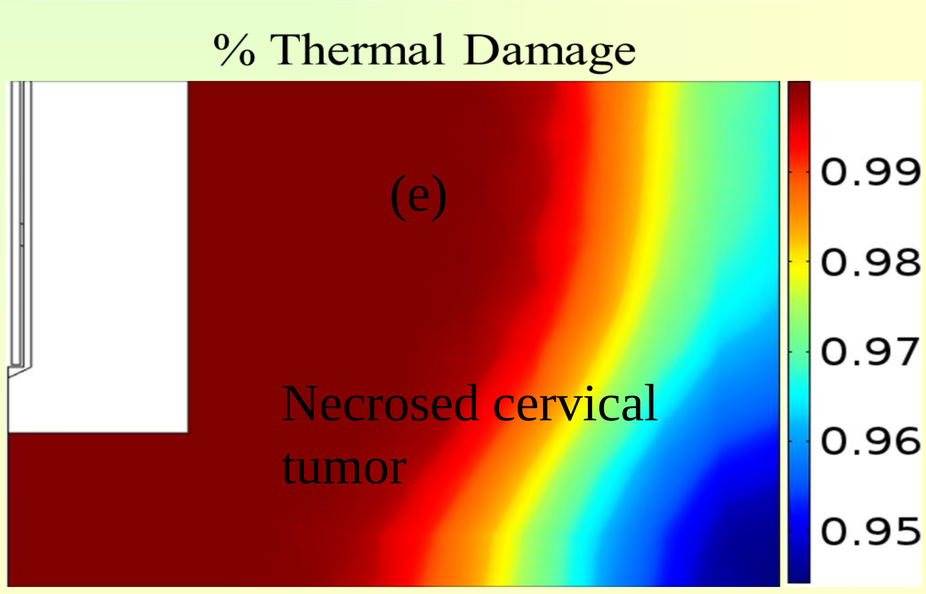
$$\frac{\partial C}{\partial t} + \nabla \cdot (D \nabla C) = 0 \qquad (4)$$

$$D = D_0 exp\left(-\frac{E_a}{R\,T(r,Z)}\right) \qquad (5)$$

RESULTS







CONCLUSION

The simulation result for prodigiosin (anti-cancer drug) released into the cervical tumor from the temperature sensitive P(NIPA) gel in Figure 1c shows a peck concentration of $\sim 0.03\,\mu mol/m^3$ in 30 min. The drug release profile indicates potential clinical relevant for effective localized chemotherapy. The predictions of temperature distribution (Figure 1d) in the cervical tumor domain are high enough to kill the cervical tumor cells. The fractional thermal damage results shows that above 0.99 of the cervical tumor model is damaged. The simulation results of the microwave heating probe/drug loaded PNIPA implanted in cervical tumor show potential application for combine localized treatment of cancer.

REFERENCES

[1] W. Bonnez and R.C. Reichman. In: GL Mandell, JE Bennett and R Dolin, (eds). Principles and Practice of Infectious Diseases. Churchill Livingstone, Philadelphia, 2000, pp. 1630-1644.

[2] Y. Danyuo, Prodigiosin Release From an Implantable Biomedical Device: Kinetics of Localized Cancer Drug Release. J. of Mater. Sci. and Eng.C. Vol. 42, (2014) 734-745.