Modeling Radiofrequency Ablation of a Spherical Breast Tumor

R. Repaka[1], S. Singh[1]

[1]Indian Institute of Technology Ropar, Rupnagar, Punjab, India

Abstract

ABSTRACT: Radiofrequency ablation (RFA) is the most promising, extensively studied and widely applied technique in clinical practice for the local treatment of solid tumors, viz., liver, kidney, lung, bone, etc. However, the application of RFA in treatment of breast cancer is still in its developing stage. The present study aims at analysing the efficacy of temperature-controlled RFA in breast tumor. A three-dimensional model of breast has been constructed to conduct thermo-electric analysis on FEM model using COMSOL Multiphysics® software. The variations of electrical conductivity and thermal conductivity along with variable blood perfusion have been accounted in this numerical analysis.
INTRODUCTION: Globally, breast cancer is the second most common type of cancer after lung cancer and the fifth most common cause of cancer death. In 2012, an estimated 23.65 million cases were diagnosed with breast cancer and close to 4.28 million deaths occurred due to breast cancer worldwide [1]. In the Indian context, roughly for every 2 women newly diagnosed with breast cancer, one is dying of it [2]. Over the past few decades, the surgical management of breast cancer has evolved significantly from radical mastectomy (surgical removal of the breast) to breast-conserving surgery (surgical removal of the tumor and surrounding tissue). Although, surgery remains the gold standard for treatment of localized breast cancer, it is a highly invasive procedure with poor cosmetic results [3]. In this context, non-surgical minimally invasive thermal ablation techniques have been explored by scientists since the advent of modern imaging with the intention of achieving equivalent efficacy with improved cosmesis [4,5]. Out of all the available thermal ablative techniques, RFA has received considerable attention. The breast as an organ seems to be an ideal model for RFA (Figure 1) because of its superficial location on the thorax and the absence of intervening organs. Further, no large blood vessels are present in the parenchyma of breast and hence convectional heat loss is unlikely to occur.

USE OF COMSOL Multiphysics® software: A 3-D model of breast along with the spherical tumor (Figure 2) and monopolar RF electrode has been constructed using geometry interface of COMSOL® software(Figure 3). The present study utilizes the electric currents (ec) physics of AC/DC Module and bioheat transfer (ht) physics of Heat Transfer Module of COMSOL Multiphysics® software to solve the coupled thermo-electric problem. We incorporated a programmable temperature-controlled RFA by employing a proportional-integral-derivative (PID) controller to monitor and maintain the tip temperature of RF electrode below a set target temperature.

RESULTS: A numerical simulation of the coupled electric field distribution and Pennes bio-

heat equation in a cancerous breast revealed a strong dependence of ablation volume on the set target temperature of RF electrode.

CONCLUSION: A finite element analysis has been performed by utilizing an automatic temperature-controlled RFA of breast tumor to capture the effect of target tip temperature on the ablation volume produced. The findings from the numerical simulation can contribute in a substantial way by providing useful insights to clinical practitioner to perform RFA of breast tumor in a more reliable and effective way.

Reference

[1] WHO REPORT 2012, www.iarc.fr, Copyright Cancer Research UK 2014
[2] Globocon 2012, “Cancer incidence and mortality worldwide: international agency for research on cancer”. www.globocan.iarc.fr
[3] Nguyen, T., Hattery, E., & Khatri, V. P., 2014. “Radiofrequency ablation and breast cancer: a review”. Gland surgery, 3(2), 128-135.
[4] Singh, S., Bhowmik, A., & Repaka, R., 2016. “Thermal analysis of induced damage to the healthy cell during RFA of breast tumor”. Journal of Thermal Biology, 58, 80–90.
[5] Ellis, L.M., Curley, S.A., & Tanabe, K.K., 2004. “Radiofrequency Ablation of Cancer: Current Indications, Techniques and Outcomes”, Springer-Verlag New York Inc.
[6] Ng, E.Y.K., Sudharsan, N.M., 2001. “An improved three-dimensional direct numerical modelling and thermal analysis of a female breast with tumour”. Proc. Inst. Mech. Eng. H. 215, 25-37.

Figures used in the abstract

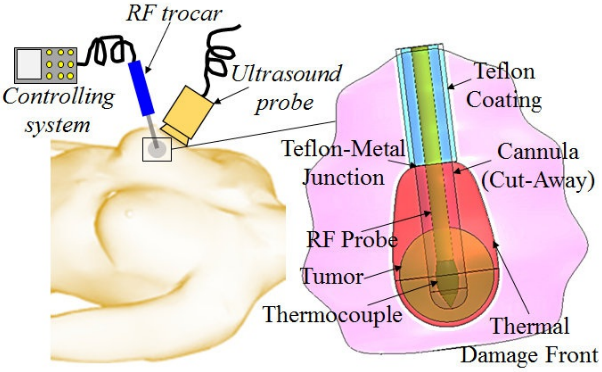

Figure 1: Schematic illustration of percutaneous radio-frequency ablation in breast [4].

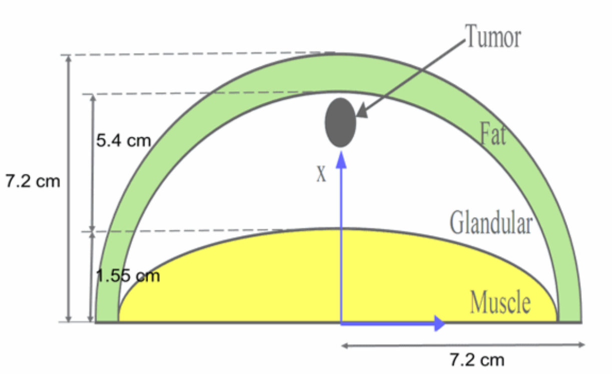

Figure 2: Schematic of sectional view of breast model [6].

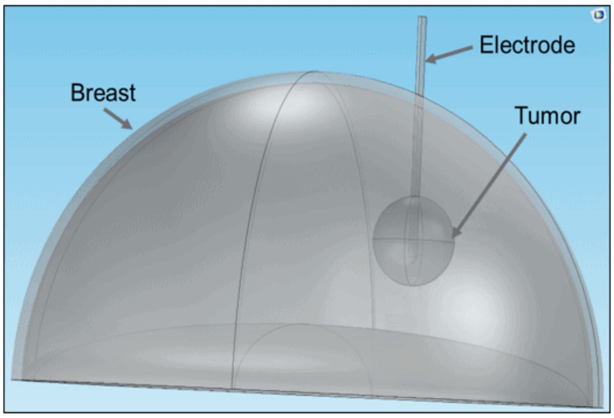

Figure 3: Schematic of 3-D model of breast in COMSOL MULTIPHYSICS® software.