Modeling of Breast Tissue with Tumor Inclusion

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Abstract

In this paper a model of breast tissue with tumor inclusion is created using a finite element method based modeling software called COMSOL Multiphysics. Fat and skin are placed to make the model more realistic. This is a 2-dimensional model. 3cm by 3.6cm area of soft tissue is modeled first. Tumor of fixed radius is included then. The Young's modulus values for fat, skin, soft tissue and hard tumors are set according to literature. More models are designed for different number, size and location of tumors. These models can be used for error analysis of elasticity imaging technique. Hence complexity and the probability of noise to measure Young's modulus for different number, size and location of tumors can be measured.

Keywords: Breast model, finite element, COMSOL Multiphysics, elasticity imaging, 2-dimensional model, error analysis.

1. INTRODUCTION

Breast cancer is the most common cancer among women, and the second-leading cause of cancer deaths in women in the United States [1]. The pathological state of the breast cancer highly correlates with their mechanical properties, such as Young's modulus (or shear modulus) and viscoelasticity [2].

Soft tissue includes the tissues that connect, support, or surround other structures and organs of the body, not being hard tissue such as bone. Elasticity imaging is a medical imaging technique that maps the elastic properties or stiffness of soft tissue and hard inclusion. It gives diagnostic information about the presence or status of disease.

The finite element method (FEM) is a numerical method for solving problems of engineering and mathematical physics. It is also referred to as finite element analysis(FEA). COMSOL Multiphysics is a cross-platform finite element analysis, solver and multiphysics simulation software[3]. It allows conventional physics-based user interfaces.

Successful elasticity images are sometimes better than conventional ultrasound for identifying tumors [5]. Malignancy and different types of cancer may be distinguishable on the basis of either strain contrast[6] or differences in geometrical appearance between conventional ultrasound and elasticity images [6-9].

Elastography has been widely used in the investigation of stiff tumors in soft tissues, such as the breast cancers (Garra et al. 1997, Hall et al. 2002, Doyley et al. 2001) and prostate cancers (Hiltawsky et al. 2001, Lorenz et al. 1999). Other applications include monitoring HIFU lesions (Righetti et al. 1999), imaging the myocardium (Konofagou et al. 2002), studying renal pathology (Emelianov et al. 1995), monitoring thermal changes of the tissue (Varghese et al. 2002) and skin abscess diagnosis (Gaspari et al. 2009).

2. COMSOL MODEL

Figure 1 shows the geometry used in the 2-dimensional (2D) finite element (FE) model of breast. The model was restricted to linear material properties. The dimensions are as follows:

- Soft tissue – 3 cm x 3.6 cm (overall).
- Tumor – 1 cm diameter.
- Skin – 3 cm x 0.1 cm.
- Fat – 3 cm x 0.5 cm.

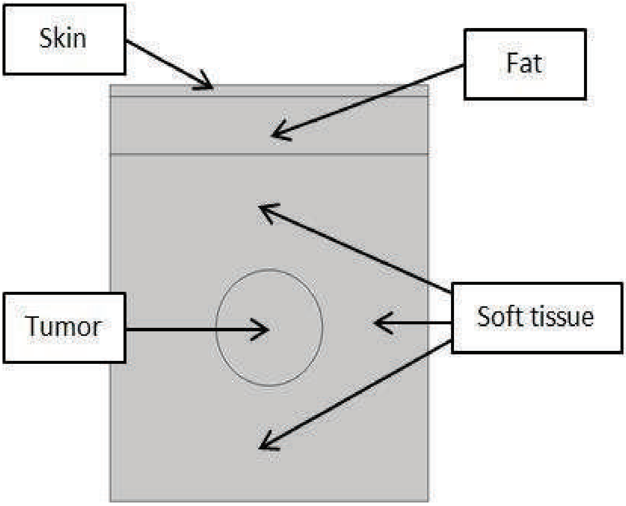

Figure 1. Gemometry of the FE model of breast tissue

3. MATERIAL PROPERTIES

The model made use of material browser to select the material named Water, liquid. From the material contents section, some properties were changed to make the section's mechanical properties as like soft tissue, tumor, skin or fat. The properties mainly changed were Poisson's ratio and Young's modulus according to the literature [4]. Poisson's ratio is the ratio of the proportional decrease in a lateral measurement to the proportional increase in length in a sample of material that is elastically stretched. Young's modulus is a measure of the ability of a material to withstand changes in length when under lengthwise tension or compression. Sometimes referred to as the modulus of elasticity, Young's modulus is equal to the longitudinal stress divided by the strain. The values set for different tissue types are given in the table.

Table 1
Mechanical properties of tissue components of breast

Tissue type	Poisson's ratio	Young's modulus(kPa)
Soft tissue	0.495	10
Tumor	0.495	40
Skin	0.495	200
Fat	0.495	1.5

4. POSITION AND SIZE OF VARIOUS TISSUE TYPES

The position and size of tissue type's namely soft tissue, tumor, skin and fat are given in the table below.

Table 2
Position and size of various tissue types

Tissue type	Position	Width(cm)	Height(cm)	Size
Soft tissue	(0,0)	3	3	(3,3)
Fat	(0,3)	3	0.5	(3,0.5)
Skin	(0,3.5)	3	0.1	(3,0.1)
Tumor is positioned at (1.5,1.5) with a radius of 0.5cm				

The geometrical models showed in the Figure 2-5 are made in COMSOL Multiphysics where size and position for different tissue types are indicated. In the Figure 2-5 specific tissue type's namely soft tissue, fat, skin and tumor are shaded in light blue color.

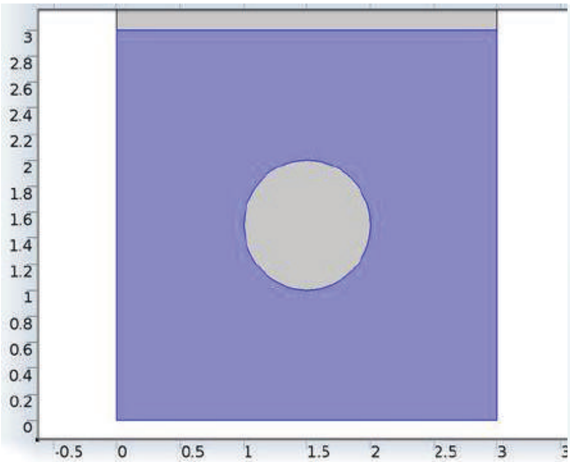

Figure 2. Position and size of soft tissue

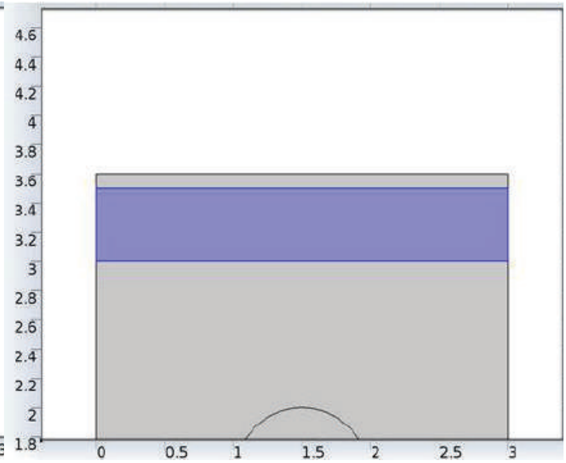

Figure 3. Position and size of fat

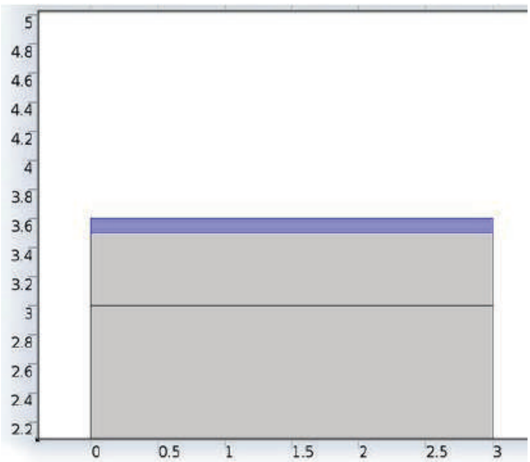

Figure 4. Position and size of skin

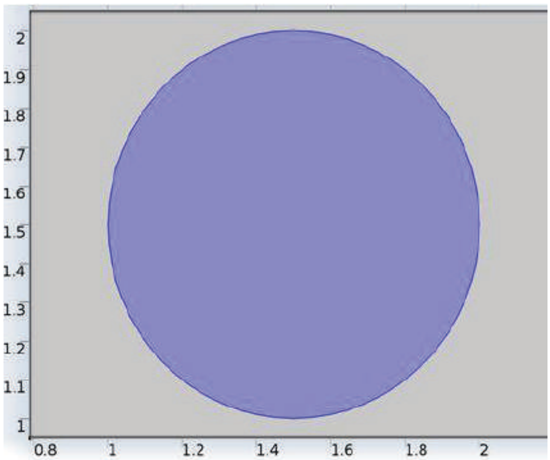

Figure 5. Position and size of tumor

5. MODELS, BASED ON DIFFERENT NUMBER, SIZE AND LOCATION OF TUMORS

More models of breast tissue are designed for different number, size and location of tumors. These models can be very effective for error analysis of elasticity imaging which method is becoming more and more reliable day by day. Those various models made in COMSOL Multiphysics are given below.

5.1 Single tumor at different positions

Tumors can be at different position for different patient having breast cancer. Here in Figure 6 the model is designed such that the tumor is at middle of the breast tissue. Figure 7-9 indicate the models where single tumor is at different edges of the breast tissue.

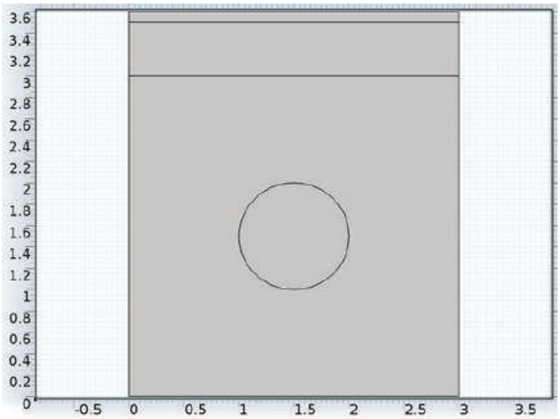

Figure 6. Single tumor at middle

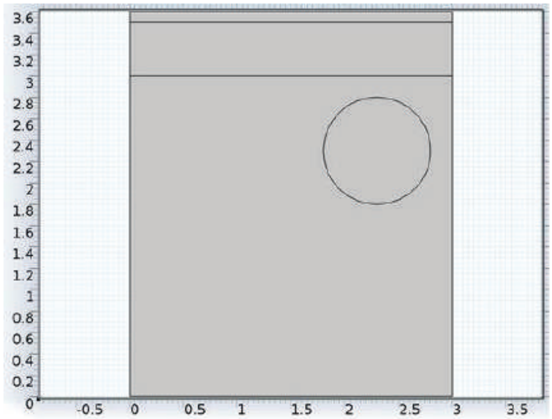

Figure 7. Single tumor at right-upper corner

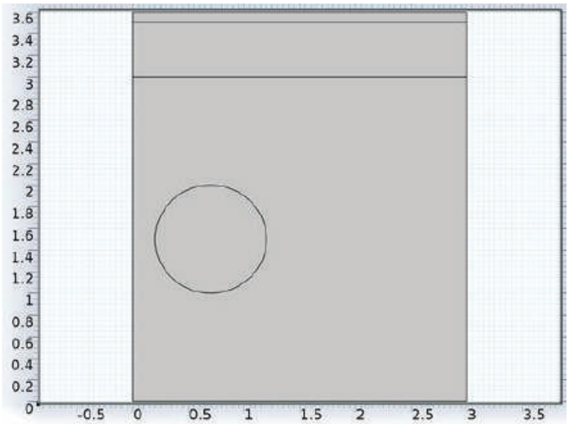

Figure 8. Single tumor at left side

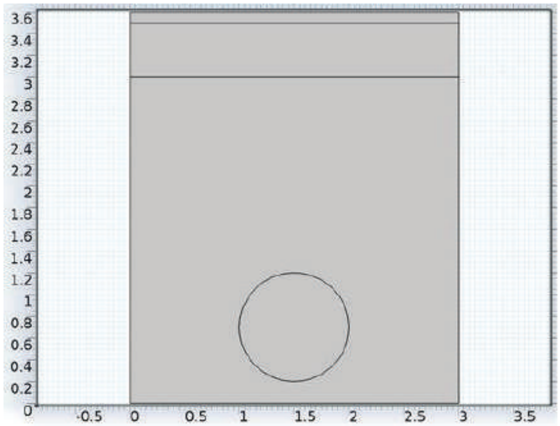

Figure 9. Single tumor at bottom

5.2 Double tumors at different positions

Patient having breast cancer might have more than one tumor. Figure 10-12 indicate the models where one big tumor is at middle and another small tumor is at different positions not overlapping the big tumor. Figure 13 indicates the model where big tumor is not fixed at the middle but positioned at the left bottom corner and small tumor is at right-upper corner.

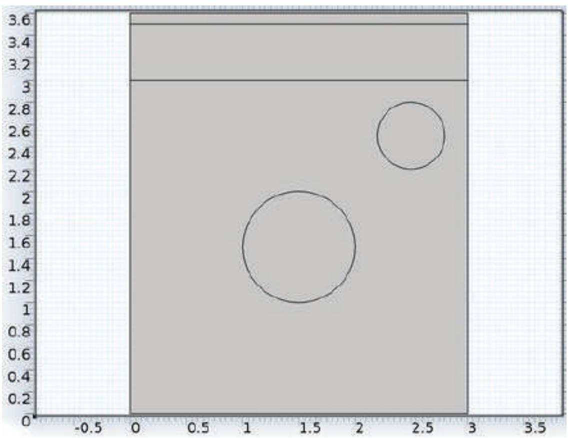

Figure 10. Big tumor at middle, small tumor at right-upper corner

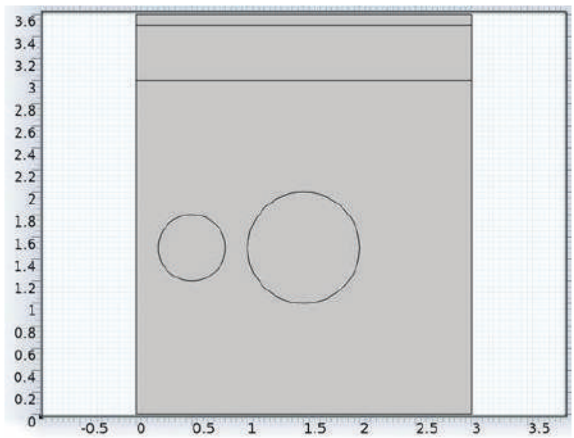

Figure 11. Big tumor at middle, small tumor at left side

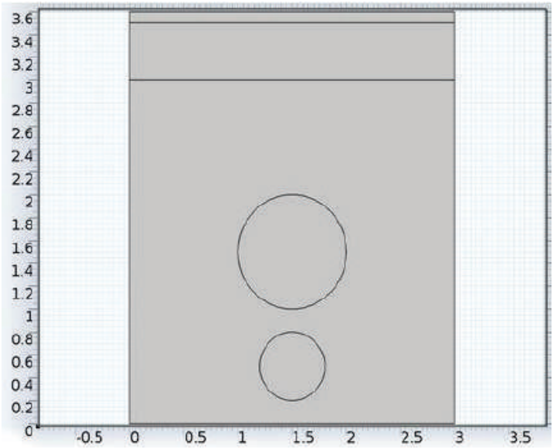

Figure 12. Big tumor at middle, small tumor at bottom

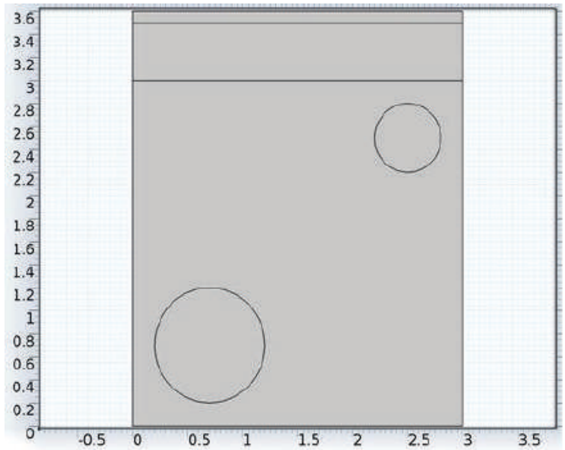

Figure 13. Big tumor at left-bottom corner, small tumor at right-upper corner

6. CONCLUSIONS AND DISCUSSION

Conventional elasticity imaging shows strain images, and can provide improved ability to determine the lesions' location and shape when compared to the corresponding B-mode imaging which is more commonly used for breast cancer detection.

Reports conclude unanimously that elasticity imaging could potentially be a useful clinical tool, but none has yet demonstrated a conclusive case for adoption into routine clinical practice.

This work can help improve the elasticity imaging technique by providing useful information about noise induction for different number, location and size of tumors. The models designed in this paper can be used for further error analysis of elasticity imaging technique. Hence contribute to the improvement in the detection of breast cancer accurately by elasticity imaging which is still in a developing state.

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