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Using elastography to predict breast cancer

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Abstract
In this work a finite element investigation carried out to predict breast cancer. Human tissues have varied rapidly stiffness. Recent approach called noninvasive elastography using the change in displacement and strain in tissues when subjected to load are used to detect the breast cancer without using biopsy or radiation. Malignant, benign and healthy tissue can be classified according to its response when simple weights (1, 2, 3 and 4 kg). Different built up equations are used in Ansys 11 to model the hyperelastic tissue behavior and simulate the soft tissue. The results show that a simple Finite element model with linear elastic material properties can be suitable to simulate the real case and can be used more to predict and comparison reason with elastography to predict the type of tumor.

Keywords: Elastography; Finite element model; Hyperelastic; Noninvasive.

1. Introduction
A malignant tumor starts in human breast to form a strange body called breast cancer. Body breast cancer forms a malignant tumor and begin to spread in healthy body places and entire breast. The breast cancer happens to women in a high percentage but men can also get it, too. 22.9 % of world cancer is breast cancer in women. Also, it is responsible of 458,503 deaths just in 2008 equivalent to 13.7% of women deaths [1]. Breast cancer considered the second most common type of cancer after skin cancer [2]. Elastography is an important technique to distinguish between soft or hard tissues in homogeneous tissues. Ophir et al. first published in elastography [3]. By considering the elasticity of tissues and calculating tissue displacement and strains. 2D elastograpphy can gives a good visualizing but 3D elastography presents better measures for many variables such as shape, size for tumor for more details see [4, 5].

2. Theoretical considerations
Regular Elastography is performed gradually by (a) subject the target with a set of ultrasonic radio frequency echo signals and collect it (b) subject the target to small axial deformation (c) collect the second set of signals as shown in Figure 1.
To get more information about stiffness of breast cancer tissue by using elastography, strain component are used especially normal axial strain. Essentially shear strain gives some information for the relation between different stiffness natures. The displacement field can be used to determine the stiffness type and classification but is more involved compared to with strain field.

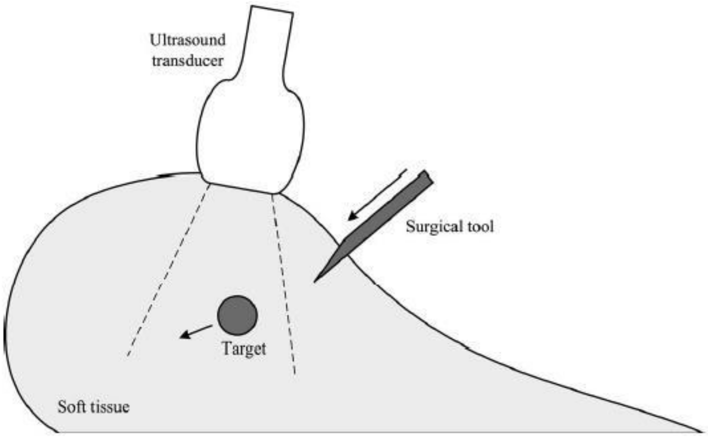


Figure 1. Ultrasound process for breast.

The field of strains can be define as follows [6],

$$\varepsilon_1 = \frac{\varepsilon_y}{2} + \sqrt{\left(\frac{\varepsilon_y}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2}$$
$$\varepsilon_2 = \frac{\varepsilon_y}{2} + \sqrt{\left(\frac{\varepsilon_y}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2}$$
$$\gamma_{max} = \sqrt[2]{\left(\frac{\varepsilon_y}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2}$$
$$VM = \sqrt{\frac{3}{2}(\varepsilon_1^2 + \varepsilon_2^2) - \varepsilon_1\varepsilon_2} \qquad (1)$$

where ε_y: the axial strain acts normally, γ_{xy} = refer to shear strain acts axially, ε_1= refers first principle strain, ε_2 = refers second principle strain, γ= refers to maximum shear strain, VM==refers to Von Misses strain, $\varepsilon_y = \frac{\partial v}{\partial y}$, $\gamma_{xy} = \frac{\partial v}{\partial x}$

The strain curve was graphed for each tissue type and recorded then may fitted using empirical equations for example equation 2 [6].

$$\sigma = A(e^{m\varepsilon}-1) \qquad (2)$$

where A and m are fitting constants and σ are the axial stress.

The following expression was derived for the relationship between sigma and strain difference,

$$\frac{(\sigma+A_2)^{m_1}}{(\sigma+A_1)^{m_2}} = \frac{A_2^{m_1}}{A_1^{m_2}}\, e^{m2m1(\Delta\varepsilon)} \qquad (3)$$

Or,

$$\Delta\varepsilon = \frac{m_1 \ln\left(\frac{\sigma}{A_2}+1\right) - m_2 \ln\left(\frac{\sigma}{A_1}+1\right)}{m2m1} \qquad (4)$$

where ‘1’ refers to the tumor mass, and ‘2’ refers to the healthy tissue. The last equation was used to plot the difference stress-strain’ trends for breast tissue types.

3. 3D elastography, phantom study (experimental approach)

Elastography technique can be achieved by experiments a phantom study and done on artificial breast for example the phantom study (CIRS, Norfolk, Virginia, USA) as shown in Figure 2 to determine the best ultrasound and imaging variables.

Human body tissue modulus effected by strain increasing strain amount gives higher human tissue stiffness. Tumor with malignant specification have will have higher stiffness than benign case subjected to load. The classification method used with the following expressions Figure 3 [7, 8].

$$If\ \Delta\varepsilon_{m4} \gg \Delta\varepsilon_{m3} \gg \Delta\varepsilon_{m2} \rightarrow Malignant\ behavior$$
$$If\ \Delta\varepsilon_{b4} \gg \Delta\varepsilon_{b3} \gg \Delta\varepsilon_{b2} \rightarrow Benign\ behavior \quad (5)$$

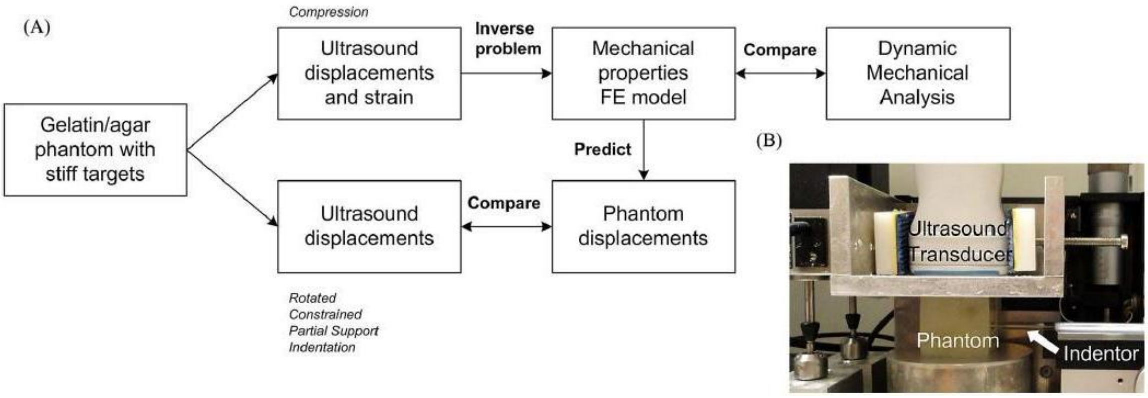


Figure 2. Phantom experimental study.

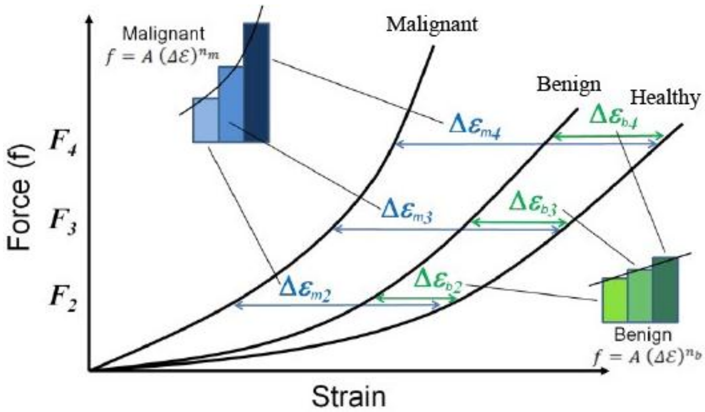


Figure 3. Approximated force strain curve used for classification.

4. Finite element elastography model

A finite element method with material nonlinear investigation was used to predict the type of tumor masses with elastography. For this purpose a finite element model with Quad 4 element are selected and a total of 2000 element, 4300 node used. A coupled degree of freedom must be applied to ensure the natural tissue phenomena as shown in Figure 4.

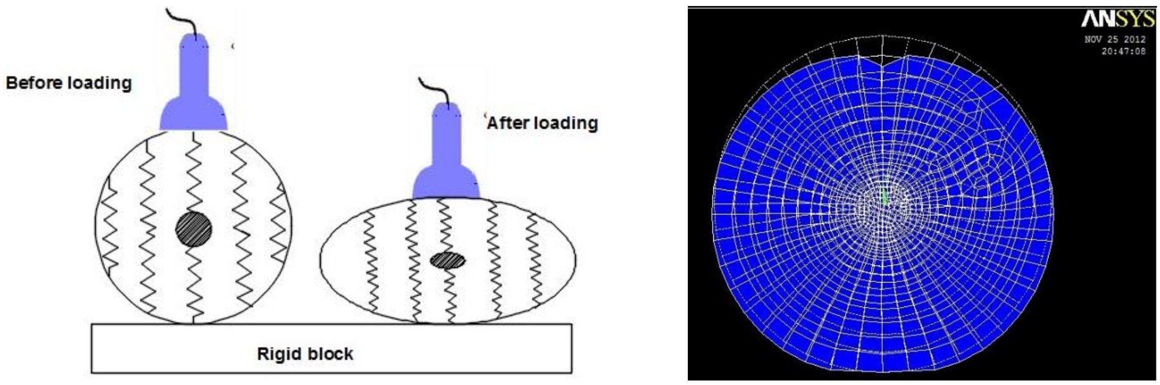


Figure 4. Finite element representative of the proposed model.

5. Results and discussions

A tumor case study was taken namely 1 cm and the breasts are 10 cm circular region. After mesh the specified region the load and boundary conditions are imposed. The ends or nodes and are assumed to be fixed boundary conditions. While the load is subject at the top of the model as 1, 2, 3 and four kgf respectively. These points are coupled to move together and simulate the real load subject. Different hyper elastic models are tested and assumed with different stress-strain curve. Experimental stress-strain curve are shown in Figure 5 [9]. Sample Ansys results for axial strain distribution in Ductal Carcinoma shown in Figure 6.

The results for finite element approach shown in Figure 7 shows that the healthy tissue tends to be more compressible than other tumor cases or having smaller stiffness magnitude.

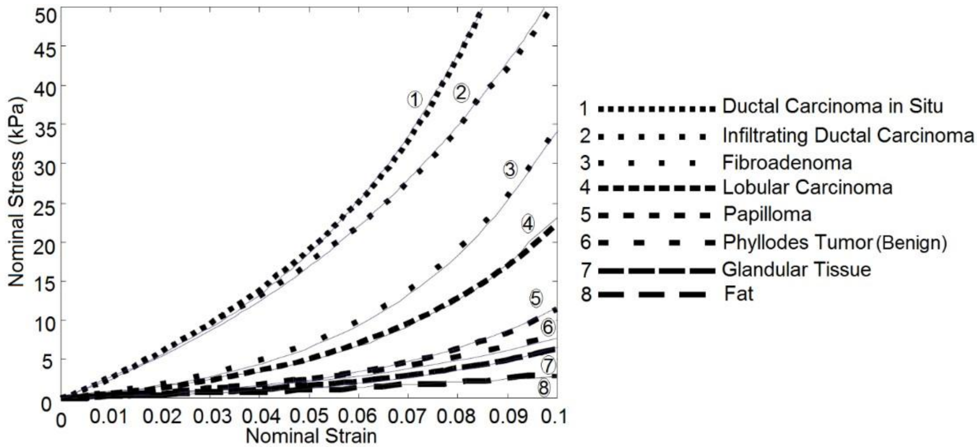
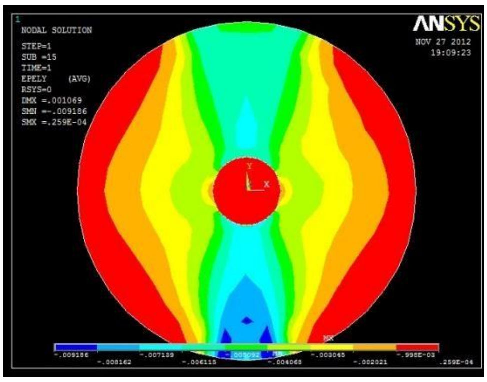
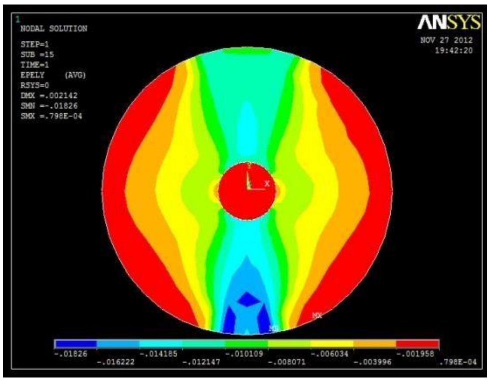


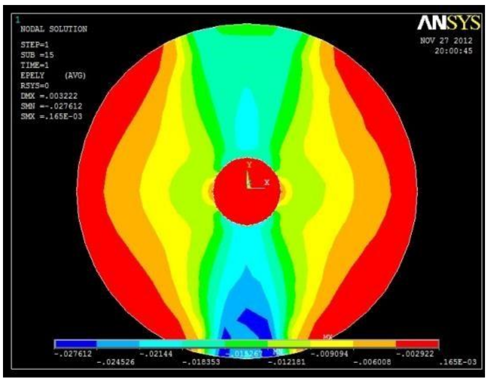
Figure 5. Experimental stress-strain curve [9].



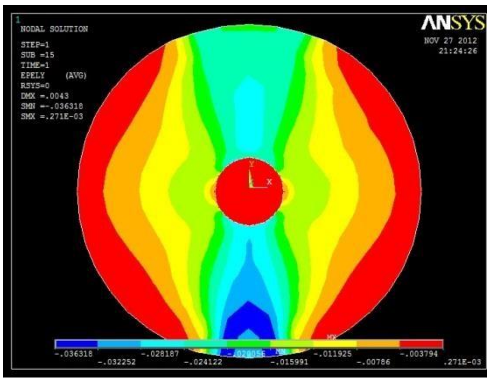
(a) Load 1 kgf



(b) Load 2 kgf



(c) Load 1 kgf



(d) Load 2 kgf

Figure 6. Axial strain distribution in ductal carcinoma.

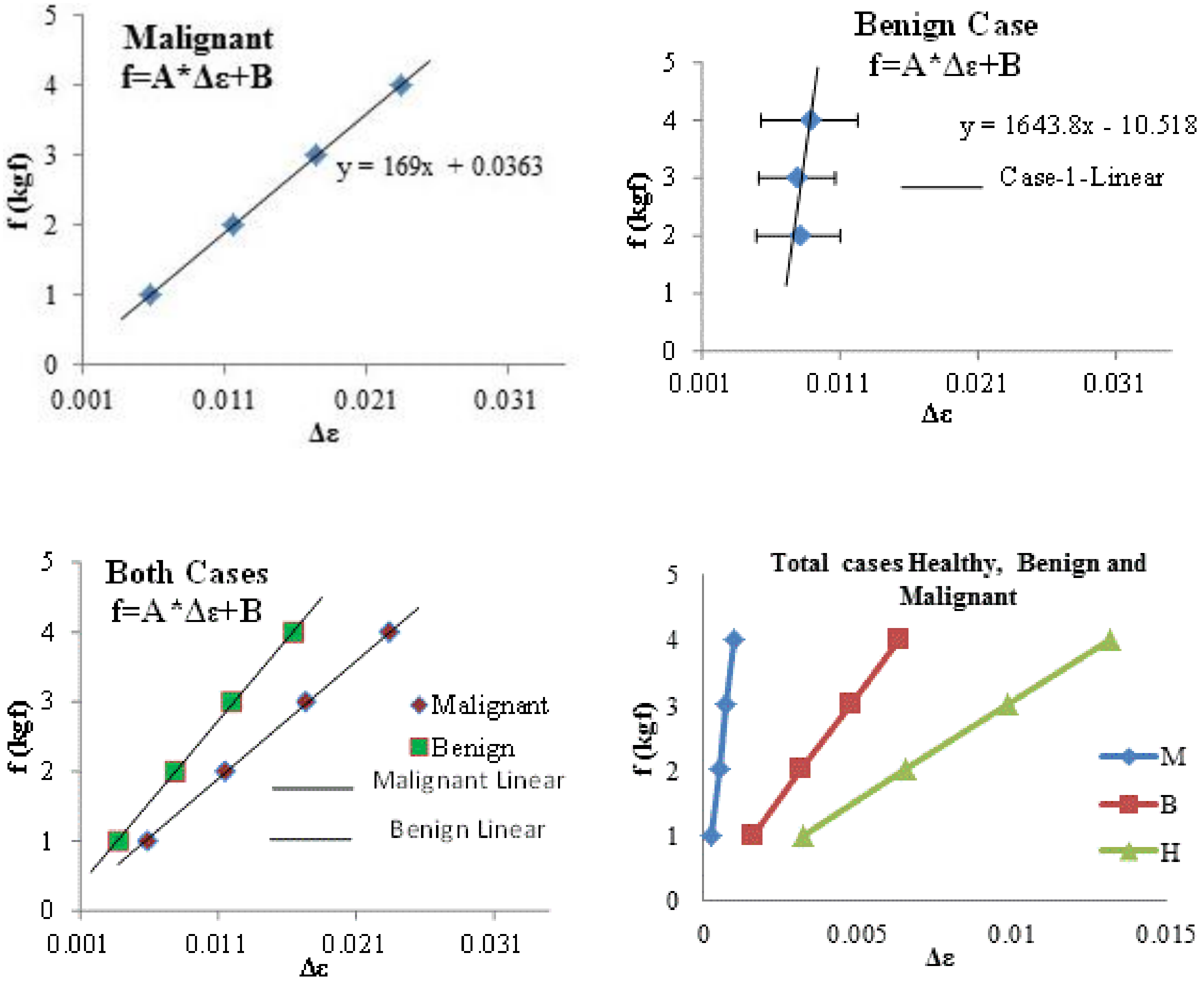


Figure 7. Axial strain for malignant, benign and healthy.

6. Conclusion

In this paper, we describe the elastography technique used to discover the breast cancer by stiffness variance.

A major conclusion may be drawn from this work:

1. Linear elastic models give good accuracy with respect to nonlinear models.
2. Finite element method is suitable for the comparison with the experimental phantom model.

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