INTRODUCTION
Multi-modality imaging of the breast obtained by mammography, MRI and PET is thought to be best achieved through some form of data fusion technique. However, images taken by these various techniques are often obtained under entirely different tissue configurations of compression, orientation or body position. In these cases some form of spatial transformation of image data from one geometry to another is required such that the tissues are represented in an equivalent configuration. While many investigators have studied the use of ad-hoc geometric transformations, they ignore the different elastic properties of the various tissue components such as fat, fibroglandular tissue and skin. We have been exploring the use of finite element method (FEM) for this purpose which reflects the biomechanical characteristics of the complex distribution of these components derived from MRI images of the breast. The problem of calculating breast tissue deformation is associated with difficulties such as complex geometry, large number of unknowns, nonlinear and visco-elastic behavior. An interesting application of this problem is MRI to mammography modality conversion. In mammography, the breast is placed and aggressively compressed between two rigid plates. In this case breast shape deformation is modeled as a contact problem. In this article, we discuss a three dimensional nonlinear FE model which we use to calculate shape deformation of breast tissue under mammography. In this model, we assume that the breast consists of fat, fibroglandular and skin.

METHODS
We use a 3-d FE model to simulate tissue deformation of breast under mammography. This is a contact problem where the boundary conditions change continuously until equilibrium is reached. Therefore, irrespective of the materials mechanical properties the problem is nonlinear. We assume that the fat, fibroglanular tissue and skin are elastic and incompressible materials. The first step in the implementation of the FEM is mesh generation. Here, because there is not a simple, analytical representation that can be used for surfaces and interfaces of the breast soft tissues, meshing is not a straightforward task. For mesh generation, we use 3-d MR images to find these surfaces and interfaces. We first apply a segmentation algorithm on the MR images to separate different materials within the breast, then use a meshing code which we have developed to read in the segmented images and produce the 3-d mesh. This mesh generation code is fully automatic and is based on the algorithms presented by Keyak et. al. 1990. We use ABAQUS (Hibbit et. al. 1998): a nonlinear finite element package to solve the contact problem. We first mesh the breast using the three dimensional mesh generation code which outputs a three dimensional mesh compatible ABAQUS preprocessor. We use eight nodded hexahedral elements which are known as well behaved type of elements to mesh the fat and fibroglandular tissue, and four nodded membrane elements to mesh the skin. After preprocessing, ABAQUS solves the nonlinear contact problem incrementally.
RESULTS

To demonstrate the capability of this model in predicting breast shape deformation, we used two sets of MR images of a breast. The first set was obtained from a breast of a female volunteer before compression and the second was obtained after applying a 48 mm (50%) compression to the breast using two rigid plates. We used the first set to obtain the mesh shown in Figure 1-a and the second one for verifying the results. Figure 1-a depicts the mesh of the breast tissues that are covered by the skin. In this mesh, there are approximately 18500 elements and 33000 nodes each of which has 3 degrees of freedom. We assume that Young's modulus of fat, fibroglandular tissue and skin are 5.0 kpa, 50.0 kpa and 500.0 kpa respectively (Sarvazian et. al. 1995). The deformed shape of the breast obtained from ABAQUS is shown in Figure 1-b. To verify the results, we present a calculated and real images of a sagittal section of the breast. These images are depicted in Figure 2. In this figure the white and dark regions represent the fat and fibroglanular tissues respectively.

CONCLUSIONS

We developed and implemented a 3-d FE model to predict breast tissue deformation under given loads or boundary conditions. This model is capable of handling large scale calculations and complicated nonlinearities such as that of contact problems. The preliminary results of this model, considering the lack of accurate information about breast tissue elastic parameters is encouraging. To improve the results we will do more research to obtain more accurate elastic parameters of the breast tissue components. The results demonstrate that this model is capable of predicting breast tissue deformation; therefore it can be used as an effective tool in data fusion techniques.

REFERENCES


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