BREAST BIOMECANICAL MODELING FOR COMPRESSION OPTIMIZATION IN DIGITAL BREAST TOMOSYNTHESIS

Mîra Anna (1,2), Ann-Katherine Carton (2), Serge Muller (2), Yohan Payan (1)

1. TIMC-IMAG Lab, CNRS & Univ. Grenoble Alpes, France; 2. GE-Healthcare, France;

Introduction

Mammography is a specific type of breast imaging that uses low-dose X-rays to detect cancer in early stage. During the exam, the women breast is compressed between two plates until a nearly uniform breast thickness is obtained. This technique improves exam quality but can be uncomfortable for the woman. Though the mammography is the most effective breast cancer screening method, the discomfort perceived during the exam could deter women from getting the test. Therefore, an alternative technique with reduced breast compression is desirable.
The aim of this work is to develop a biomechanical Finite Element (FE) breast model in order to analyze different breast compression strategies and their impact on image quality. Large breast deformations will be simulated using this FE model. A particular attention will be granted to the computation of the initial stress in the model due to gravity and to boundary conditions imposed by the thorax anatomy. Finally, the model will be validated by comparing the estimated breast deformations under gravity load with the experimental ones measured in three body positions: prone, supine and oblique supine (Fig. 1).

Methods

The complex breast anatomy is considered including the skin, muscles, suspensory ligaments and adipose, glandular and connective tissues. Most breast tissues in the literature are modelled as neo-Hookean materials (Table 1) [1].

Fat	Glandular	Skin	Ligaments
5-25	10-60	88-480	30*10e3

Table 1: Elastic Modulus (kPa) proposed in the literature for various breast tissues [1].

The 3D breast geometry is reconstructed using MRI images. The images are segmented using ITK-SNAP software [2] (Fig. 2a). A two-step segmentation technique is used: first a velocity map is computed using random forest classification, then a region growing based on active contours is applied. Finally, binary mathematical morphology operations are applied to fine-tune the segmentation.
The 3D breast geometry is discretized with a hexa-dominant FE meshing tool [Texisense Inc.] and is the subject of a hyper-elastic quasi-static simulation within the ANSYS software framework (Fig. 2a).

Results

The image data are acquired on three volunteers with various breast dimensions. Three positioning configurations are considered for each volunteer (fig. 1). All volunteers agreed to participate in this experiment within a pilot study approved by an ethics committee.

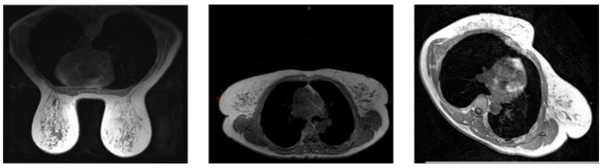
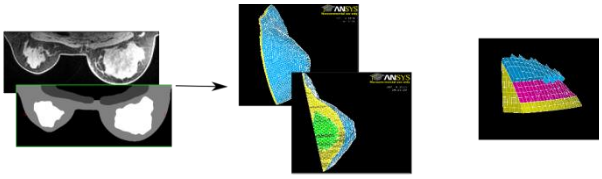


Figure 1: MR images for three breast configuration: a) prone position; b) supine position c) oblique supine.

Segmented breast images enable to compute a patient-specific FE mesh including skin, fat, ligaments, glandular and muscular tissues (Fig. 2b). A special attention is brought to the simulation of breast fasciae.



a) b)

Figure 2: a) Patient specific mesh generation. b) Modeling of breast fascia behavior.

Discussion

Previously developed biomechanical breast models are restricted to modeling adipose and fibroglandular tissues only. However, breast reconstruction surgery has proven the importance of suspensory ligaments and breast fasciae on breast mechanics [4]. Our model takes into account these structures to improve current biomechanical modeling of the breast. The pectoral muscle will also be considered to define realistic boundary conditions.
MRI images acquired in three different breast configurations will be used to validate the relevance of our biomechanical model.

References

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