BIOMECHANICAL MODEL EVALUATION USING NON-RIGID IMAGE REGISTRATION APPLIED TO BREAST MRI.

Anna Mira (1), Thiranja P. Babarenda Gamage (1), Anthony J. Doyle (2), Yohan Payan (3), Poul M.F. Nielsen (1,4), Martyn P. Nash (1,4)

1. Auckland Bioengineering Institute, University of Auckland, New Zealand
2. Faculty of Medical and Health Sciences, University of Auckland, New Zealand
3. TIMC-IMAG Lab, CNRS, Université Grenoble Alpes, France
4. Department of Engineering Science, University of Auckland, New Zealand

Introduction

Biomechanical modelling of breast tissues is widely studied for various medical applications. Several research teams have used finite element models of the breast to provide information on tissues motion during body repositioning. However, due to a lack of data describing displacement of internal soft tissues, the model evaluation methods were often incomplete, with the error estimation being limited to a small number of subjects [1] or to surface data assessment [2].
The aim of this work was to develop a numerical framework allowing to quantify regional errors in the model predicted soft tissue motion using in-vivo measurements. The framework uses image registration techniques to compute the displacement field between two breast configurations.

Materials and Methods

Soft tissue displacements between two body positions were described using a rigid and an elastic transformation. In this work, the displacement field between supine and prone breast configurations is computed. Figure 1 shows the overall image registration process. First, a rigid transform is initialised using an iterative closest point algorithm to minimise the Euclidean distance between two sternal landmarks. Then, the rigid transform is optimised using a gradient descent algorithm to minimise cross-correlation between the images [3]. To remove any non-rigid deformation, the image similarity metric is computed over the sternal area only. The sternum alignment was verified by comparing the positions of 24 bony landmarks. The landmarks were manually selected for 6 subjects along the articular facets of the sternum body from the 3rd to the 5th rib.

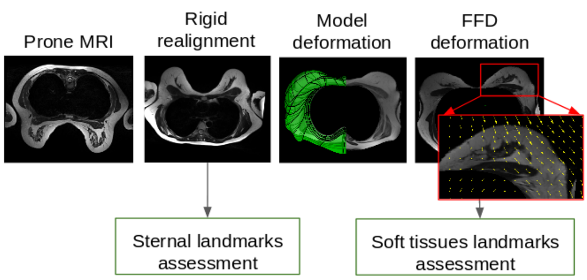

Figure 1: Numerical framework to compute soft tissue displacement field between prone and supine body positions.

To estimate the elastic transform, first, the soft tissue displacements were computed using a finite element model of the breast [2]. Then, the model estimate was used to initialise a multi-resolution free-form deformation image registration method [3].
The global displacements estimated using image registration were compared to the position of 419 landmarks (cysts, fibroadenoma, lymph nodes, and nipples) that have been manually identified across 70 healthy participants by 2 clinical registrars.

Results

The rigid alignment error was measured in terms of mean Euclidean distance between estimated rib landmark positions and their associated positions in the supine configuration. The mean±standard error measured over 6 subjects was 2.51±0.18 mm. The maximal mean distance was 3.13±1.29mm.
The estimates of soft tissue global displacements will be evaluated soon and the corresponding results will be presented during the conference.

Discussion

The proposed numerical framework allows us to compute the displacements of internal soft tissues between two different breast configurations. The estimated displacement fields can be used as a gold standard for the evaluation of existing biomechanical models [1,2]. Using the model, regional errors introduced due to the impact of different boundary conditions or anatomical structures will be analysed. In future, these results will provide a baseline for the development of a new state of the art biomechanical model.

References

1. Babarenda Gamage et al.,Comput Biomech Med, 123-134, 2017
2. Mîra et al, Clin Biomech, 60:191-199, 2018.
3. Yoo et al., Stud Health Technol Inform, 586-592, 2002
4. Schnabel et al, Med Image Comput Comput Assist Interv, 573-581, 2001.

Acknowledgements

We thank Breast Cancer Foundation NZ and PHC Dumont d'Urville for financial support.
The authors thank Ben Addison and Clarke Baker for providing manual selection of anatomical landmarks.