COMPUTATIONAL SIMULATION OF EFFECTS OF THE MORPHOLOGY OF FIBROGLANDULAR TISSUES ON PROJECTED BREAST DENSITY CHANGES AFTER BREAST COMPRESSION BASED ON 3D MRI

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Background and Purpose: To date, no means to prevent breast cancer has been discovered. Early detection of breast cancer by X-ray mammography can increase survival rate for patients. Mammographic density (i.e. breast density) is a quantitative estimate of the ratio of fibroglandular tissue to the total breast tissue. Breast compression is essential in mammography to flatten the breast and then reduce the breast thickness, which not only can improve the image quality but also reduce the radiation dose to the patient[1-2]. However, the breast density depends on the projection angles, compression levels, the patient positions, and radiologist technician techniques[3-4]. Different projection angles can result in different breast densities even for the same patient and radiologist technician. Usually, a breast tumor is harder than any tissue around it and the shape of benign masses is round or oval. By contrast, a malignant tumor is irregular in shape and has the invasive characteristics. Little is known about the influence of the morphology of fiborglandular tissues on breast density. Fibroglandular tissues would affect breast density. Breast compression changes breast density that indirectly influences the assessment of breast cancer risk. Thus, the purpose of this study is to investigate the effect of the morphology of fibroglandular tissue on the projected breast density after the breast compression based on a non-linear deformation using patient-specific magnetic resonance images.

Materials and Methods: In this study, one hundred sixty MR slices were used to cover the whole breast. All 3T MR images were obtained with the patient in the prone position. Two different morphological types of fibroglandular tissues were used, as shown in **Fig.1**. The field of view (FOV) at acquisition was 330 mm. Image data were reconstructed within a 512× 512 matrix at a slice thickness of 1 mm. These MR images had a voxel dimension of 1.3 ×1.3×1 mm^3. A flow chat for breast simulation was displayed in **Fig. 2**. As acquired the patient-specific prone MR images, we further need to segment into the breast and fibroglandular tissues and then individually assign tissue properties for simulation[3]. Since the fibroglandular tissue is a high individually variability with irregular shapes, here we need to semi-automatically segment the fibroglandualr tissue from the whole breast tissue. The segmentation images of the breast were reconstructed from breast 3T MR. The 3D surface mesh of the breast and fibroglandular tissues were created by the Amira software package. The finite volume mesh of the breast was generated by the MSC.Marc software package. In addition, we qualified the projected breast density change (i.e., projected area ratio of fibroglandular to breast) after breast compression.

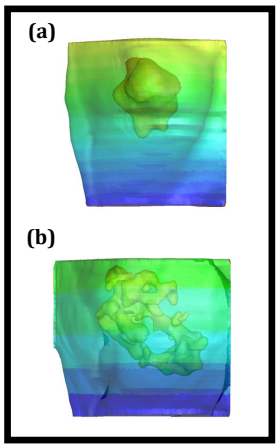

Fig. 1. (a)Centralized type of fibroglandular tissue; (b)Irregular type of fibroglandular tissue.

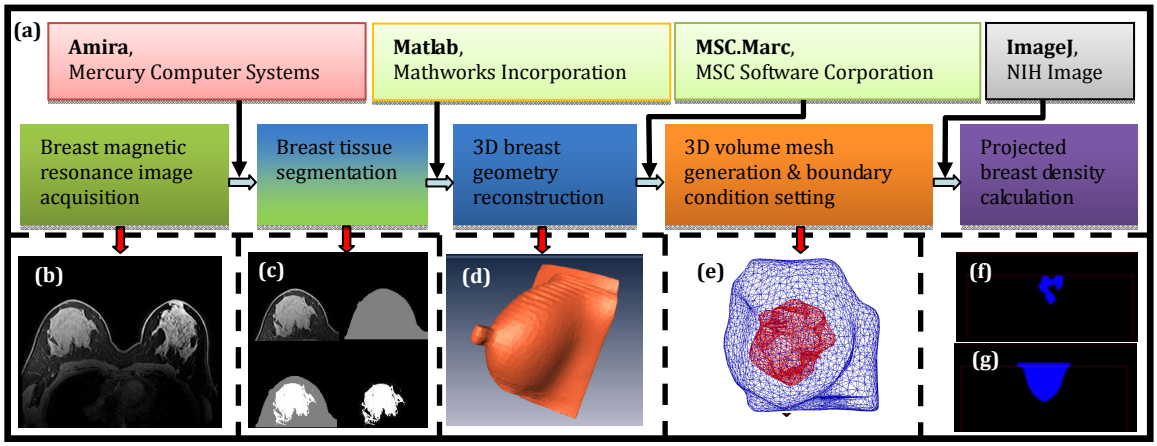

Fig. 2. (a)A flow chart of patient-specific MR images, 3D geometry reconstruction, mesh generation, simulation analysis of breast compression, and software tools for each stage; (b)Breast MR image; (c)The segmentation of breast tissue and fibroglandular tissues (white part); (d)3D right breast surface generation with 17,992 triangular elements; (e)Volume mesh for breast tissue and fibroglandular tissue(red part); (f)Projected area of the fibroglandular tissue on the projection compression plane(i.e., projection plane on the compression paddle); (g)Projected area of the breast tissue on the projection compression plane.

Results and discussions: While the compression paddles were moving along the compression direction, the posterior breast (i.e., the chest wall on ribcage) was fixed in the y-axis direction (i.e., the boundary condition) thus, the breast deformation was restricted within the space between the compression paddles and extended largely in the two other directions; that is, the breast tissue was pushed away from the chest wall. The projected area changes at different compression ratios for fibroglandular tissues and fatty tissues, as shown in **Figs. 2** (f) and (g), respectively. With cranio-caudal(CC) and mediolateral-oblique(MLO) view compressions, the projected breast density(i.e., projected area ratio) changes at compression ratio ranging from 0 to 60% were listed in **Table 1**. Higher compression ratio has a larger projected area. For the centralized type, the change of projected breast density is small for CC or MLO compressions. Moreover, the projected breast density has a lager difference between CC(i.e. 44.7%) and MLO(i.e. 48.9%) view compressions for the irregular type of fibroglandular tissue. For centralized type, at the same compression ratio of 60%, the projected area ratios were 42.1% and 41.2% for CC and MLO view compressions, respectively.

Table 1. Projected breast density (%) at different compression ratios with cc and mlo compressions

		Compression ratio (%)						
		0	10	20	30	40	50	60
Irregular type	cc	38.4	38.7	39.2	37.7	41.0	42.6	44.7
(Subject #1)	mlo	44.3	44.2	44.6	45.2	45.9	46.8	48.9
Centralized type	cc	40.5	40.4	40.4	40.4	40.6	40.9	42.1
(Subject #2)	mlo	39.1	39.1	39.0	39.1	39.3	39.9	41.2

Conclusions: It is becoming clear that different compression levels obtain different projected breast densities. For centralized type, the projected breast density may slightly be changed at different compression ratios. Here, we may not only provide a novel computer simulation approach of breast compression but also obtain the projected breast density of different fibroglandular tissue morphologies from MR images for different compression levels, CC and MLO view compressions.

References:[1]Yaffe et al., Breast Cancer Research, Vol. 10, 2009, pp.1-10. [2]Boyd et al., The New England Journal of Medicine, Vol. 356, 2007, pp.227-236. [3]Shih et al., Physics in Medicine and Biology, Vol. 55, 2010, pp.4153-4168. [4] Kopans , Radiology, Vol. 246, 2008, pp.348-353.

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