Quantitative Analysis of Projection Breast Density Changes at Different Compression Angles Based on 3D MRI

T-C. Shih[1,2], J-H. Chen[2,3], D. Chang[3], K. Nie[3], M. Lin[3], O. Nalcioglu[3], and M-Y. L. Su[3]

[1]Department of Biomedical Imaging and Radiological Science, China Medical University, Taichung, Taiwan, [2]Department of Radiology, China Medical University Hospital, Taichung, Taiwan, [3]Tu & Yuen Center for Functional Onco-Imaging, University of California, Irvine, CA, United States

Background and Purpose: Mammography is an effective tool for detecting early signs of breast cancer. Mammographic density has been found to be associated with risk of breast cancer [1-3]. To flatten the breast and reduce the breast thickness, breast compression is essential in mammography. Since the measurement of breast density comes from projection images, it may vary with projection angles, compression levels, and the patient's position. The projection effect was described by Kopans using a projection concept with stacking cubes [3]. However, it indeed lacks a realistic human data of projection information. Due to the complex of a specific-patient geometry reconstructed from a sequential scanned an extracted or segmented images, some studies used the commercial packages to simulate the breast compression; however, in their models the breast phantom was either in a simplified geometry or without considering fibroglandular tissues. Therefore, this study aims to demonstrate the effect of compression angle on the projection breast density at different compression ratios based on the patient-specific three-dimensional MR images. Compression angle of deviation was also investigated for craniocaudal (CC) and mediolateral oblique (MLO) view compressions.

Methods: Thirty-two MR slices were used to cover the whole breast. All MR images were obtained with the patient in the prone position. The field of view (FOV) at acquisition was 380 mm. Image data were reconstructed within a 256× 256 matrix at a slice thickness of 4 mm. These MR images had a voxel dimension of 1.5 ×1.5×4 mm^3. The segmentation of fibroglandular tissues based on MR images was performed with a semiautomated method proposed by Nie *et al.*[4]. The segmentation results were shown in **Fig. 1**. Here we used the left breast for compression simulation analysis. Acquisition of the three-dimensional breast surface is the first step toward simulating the breast compression. Using the Avizo® 6.0 software package (Visage Imaging Inc., Carlsbad, California, USA), the surface mesh was created in terms of triangular surface elements. The triangular surface elements were covered totally over the breast surface. Due to the irregular shapes from the segmentation 2D images, the resulting triangulation surface mesh has a huge amount of triangles on the breast tissue. In order to the quality of volume mesh, we need to remove the duplicate nodes and the collapsed elements from surface mesh that created in Avizo® 6.0. The 3D geometry was reconstructed by Avizo® 6 software, as shown in **Fig. 2**. The fibroglandular tissue and tatty tissue were described by 3,488 and 11,803 tetrahedral elements. As the large deformation of compressed breast tissue, we used a nonlinear elastic model to simulate the breast compression deformation, in which the Mooney-Rivlin material properties were used for the fatty (C_{01}=1,333 Pa and C_{10}= 2,000 Pa) and fibroglandular (C_{01}=2,333.3 Pa and C_{10}=3,500 Pa) tissues. The MSC.Marc software was used to simulate the nonlinear deformation of breast compression. The finite element method was used for analyzing the deformation of compressed breast tissues under applying an external force by compression paddles. Besides, five compression angles were used for analysis, as shown in **Fig. 3**.

Results and Discussion: Figure 4 shows the projection area changes on compression paddles with compression ratio varying from 0 to 70% for fibroglndular and breast tissues. It is clear that projection area becomes larger with increased compression ratio for CC and MLO view compressions. Here the percentage of projection breast density was defined as the ratio of the projection area of fibroglandular tissue to that of whole breast tissue on compression paddles. Table 1 listed the percentage of projection breast density varying with different compression levels. For the CC view compression, the percentage of breast density changed from 0.6149 at 10%, increased to 0.6473 at 50%, then further to 0.6924 at 70%. Within 50% to 70% compression ratio, the variation of the measured projection breast density was approximately 7%. In contrast, the variation of the projection breast density was nearly 11% for MOL view compression. In MLO+5 view compression (i.e., angle deviation of 5 degrees), the variation of the projection breast density was as large as 13% for the compression ratio varying from 40% to 70%.

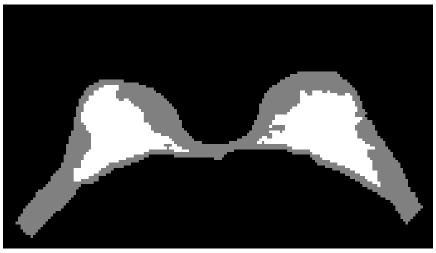

Fig. 1. The fibroglandular tissues were segmented from MR images. The white regions were indicated as the fibroglandular tissue.

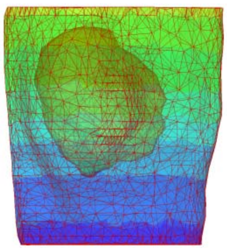

Fig. 2. The surface of the whole breast and the surface of the fibroglandular tissue were presented. The 3D surface of fibroglandular tissue is in the breast.

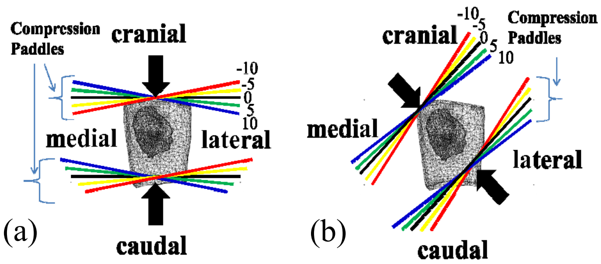

Fig. 3. The five compression angles were used as -10, -5, 0, 5, and 10. (a)CC view compression with angle deviation from -10 to 10 (b)MLO view compression with angle deviation from -10 to 10.

Table 1 Percentages of Projection Breast Density at Different Compression Ratios

	Compression ratio (%)							
	0	10	20	30	40	50	60	70
CC-10	59.87	59.69	59.70	60.02	60.79	62.01	*	
CC-5	60.61	60.63	61.22	61.92	63.13	63.76	65.09	*
CC	61.36	61.49	61.76	62.36	63.38	64.73	66.28	69.24
CC+5	61.22	61.38	62.38	63.17	63.93	64.88	65.66	66.76
CC+10	60.34	60.80	61.74	62.60	63.29	64.08	65.06	67.04
MLO-10	55.17	55.12	55.29	55.58	55.83	56.05	57.90	59.94
MLO-5	54.61	54.61	54.31	54.01	53.67	53.23	54.04	56.94
MLO	53.63	53.63	53.33	53.15	52.64	53.24	55.41	58.92
MLO+5	52.69	52.43	52.29	52.07	51.98	53.11	55.52	59.07
MLO+10	52.03	52.03	51.80	51.78	52.09	53.28	54.77	57.35

* indicates the tissue damage that cannot be subjected to an external force to compress.

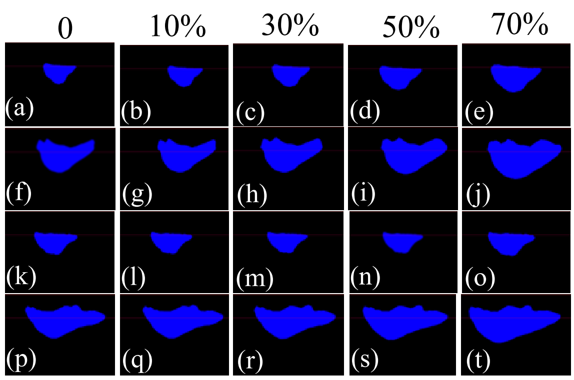

Fig.4. Projection areas at different compression ratios were presented. (a)-(j) and (k)-(t) were for CC view compression and MLO view compression, respectively. (a)-(e) and (k)-(o) for fibroglandular tissues;(f)-(j) and (p)-(t) for breast tissues.

Conclusion: This study provides a novel computer simulation approach to simulate the large deformation of breast compression. Compression angle of deviation may affect the measured projection breast density. Furthermore, the measured projection breast density may change with compression ratio.

References:[1]Mawdsley G.E. et al, *Medical Physics*, vol. 36, 2009, pp.577-586. [2]Boyd N.F. et al., *The New England Journal of Medicine*, vol. 356, 2007, pp.227-236. [3]Kopans D.B., *Radiology*, vol.246, 2008, pp.348-353. [4]Nie K. et al., *Medical Physics*, vol.35, 2008, pp.5253.
Acknowledgments: This study was supported in part by NSC 98-2221-E-039-001 and partly by CMU98-S-49.