Quantitative Analysis of Breast Parenchymal Patterns Using 3D Fibroglandular Tissues Segmented Based on Breast MRI

K. Nie[1], J-H. Chen[1,2], C-C. Hsu[2], H. Nguyen[1], M. Lin[1], T-C. Shih[1,2], D. Newell[1], B. Feig[1], O. Nalcioglu[1], and M-Y. L. Su[1]

[1]Tu & Yuen Center for Functional Onco-Imaging, University of California, Irvine, CA, United States, [2]Department of Radiology, China Medical University, Taiwan

Purpose

Mammographic density and fibroglandular parenchymal patterns have been shown to be related to the risk of developing breast cancer [1]. Women carrying BRCA-1 and BRCA-2 gene have a high risk of developing breast cancer, and compared to women with low-risk, they have denser and more heterogeneous parenchymal pattern on mammography [2]. Adipose tissue in the breast has been shown to play a role in development of mammary gland, as well as in the growth of mammary carcinoma cells and their ability to metastasize [3]. Therefore, the architecture between the fibroglandular tissue and the fatty issue may be associated with the susceptibility of developing breast cancer. Mammography takes 2D projection images of the compressed breast, thus can not provide detailed information for assessment of breast density and the parenchymal pattern. MRI provides 3D images that allows for evaluation of the fibroglandular parenchymal pattern. In this study we applied the segmentation method that we have developed to differentiate between two distinctly different parenchymal patterns using quantitative parameters, one pattern with intermingled fat-fibroglandular tissues vs. the other with confined fibroglandular tissue surrounded by fat. Then we further investigated the dependence of the morphology parameters on age and race.

Methods

A total of 195 consecutive patients with age and race information were included in this study. The MRI studies were acquired from May 2004 to June 2006 using a Phillips Eclipse 1.5T scanner. Only the normal breast that did not harbor any abnormal findings was analyzed. For the extremely fatty type (N=48), the segmentation of fibroglandular tissue is not reliable, thus they were excluded for morphology feature analysis. The parenchymal patterns of remaining cases were visually categorized into two types, Type I: the fat and fibroglandular tissues are mixed together (N=87); and Type-II: fibroglandular tissue is inside surrounded by fat outside (N=60). Two case examples, one from each type, are demonstrated in Fig. 1. The breast and fibroglandular tissues were segmented on each slice using our previously published methods [4], then combined into a 3D view as shown in Fig.1. A total of 9 features (the percent density plus 8 morphology parameters analyzed from the 3D fibroglandular tissues) were obtained to characterize each case. Statistical analyses were performed to evaluate the age- and race- association of all parameters.

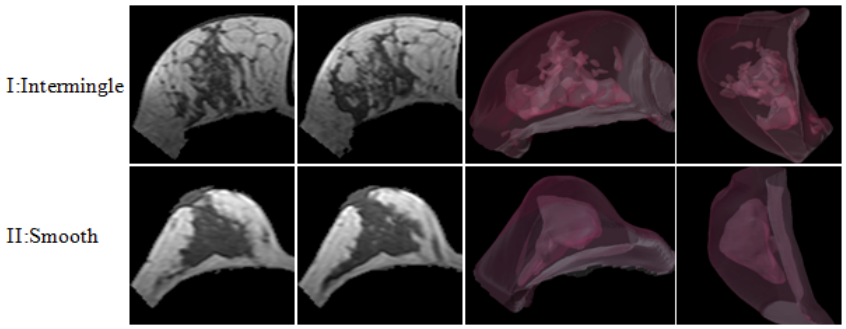

Figure 1: Two parenchymal patterns, I: intermingled, II: fibroglandular surrounded by fat.

Parameter	Mean ± Stand Deviation		P value
	I: Mixed (N=87)	II: Central (N=60)	
Age	51±9	52±11	NS
Percent Density	0.14±0.06	0.16±0.11	NS
Fibro Volume	110±61	118±78	NS
Surface Area	427±184	285±187	0.001*
NRL_mean	0.43±0.07	0.40±0.06	0.01*
NRL_entropy	0.14±0.05	0.21±0.01	<0.01*
NRL_ratio	0.15±0.02	0.15±0.02	NS
Circularity	2.7±0.39	2.6±0.49	NS
Compactness	18.8±6.8	8.2±4.0	<0.001*
Roughness	0.14±0.05	0.17±0.07	0.004*

Table 1: Comparison between Type-I & II patterns

Results

The two examples shown in Fig. 1 clearly display distinctly different parenchymal patterns, but with similar percent density (I: 16.1% vs. II: 15.6%). The compactness index (defined as the surface area over the volume of the fibroglandular tissue) is 22.7 for the mixed pattern, and 3.0 for the central pattern. The mixed case has a much higher perimeter on each imaging slice thus yielding a high compactness index. The results of all morphological features calculated from the segmented tissues for all Type I (mixed) and II (central) cases are summarized in Table 1. The mean percent density is 14% for mixed type, and 16% for central type, not significantly different. Five morphological features showed significant differences, suggesting that these descriptors may be used to quantitatively characterize the parenchymal patterns. The compactness index was the most sensitive parameter to differentiate between these two parenchymal patterns.

The association of the analyzed parameters with different racial background was analyzed, shown in Table 2. The fibroglandular tissue volume or the percentage (over the total breast volume) was comparable between the three race groups (White, Hispanic, Asian), not showing significant differences. But all 5 morphology parameters (Surface Area, NRL_mean, Entropy, Compactness, Roughness) showed significant race-association. The White and Hispanic women were more likely to present the mixed pattern (51/79, 65% and 19/28, 68%, respectively) compared to the Asian women (15/37, 41%, p=0.03). The age-association shows very different results; all 5 parenchymal morphology parameters did not show significant age-dependence, but the percent density decreases significantly with age (p=0.001).

Table 2. The breast parenchymal descriptors among three race groups

	# Case (I/II)	Age (y/o)	% density	FibroVolume	SurfaceArea	NRL_mean	Entropy	Compactness	Roughness
White	51/28	52±9	14.1±5.7	109±55	432±186	0.44±0.06	0.14±0.08	17.6±7.0	0.14±0.07
Hispanic	19/9	50±12	14.3±7.4	114±63	470±212	0.45±0.06	0.14±0.08	18.6±9.2	0.13±0.06
Asian	15/22	51±11	17.5±9.2	116±94	362±195	0.42±0.07	0.18±0.09	12.6±6.2	0.16±0.05
P-Value	0.03*	NS	NS	NS	0.04*	0.02*	0.003*	0.001*	0.02*

Discussion :

In this study, we applied a quantitative analysis method to characterize the 3D distribution of fibroglandular tissues using morphological features; also the percent density was measured. We first demonstrated that 5 morphology parameters could distinguish between the intermingled pattern and the central pattern. We further analyze the dependence of these parameters with age and race, and found very interesting results. While the percent density showed a clear age-dependence (a well-known fact), it was not race-dependent (as fatty breasts have been excluded for this study). On the other hand, the morphology parameters showed race-dependence, but not age-dependence. The White and Hispanic women were more likely to present mixed patterns, and the Asian were more likely to present the central pattern. The Asian women had slightly lower breast cancer risk, and whether it is related to the central parenchymal pattern warrants investigation. Our method described here will facilitate the investigation of the relationship between breast parenchymal pattern and the cancer risk, which could not be performed on projection mammography due to the tissue-overlapping problem.

References: [1] Li et al. Acad Radiol 2005;12:863-73. [2] Huo et al. Radiology. 2002;225:519-26. [3] Celis et al. Mol Cell Prot. 2005;4:492-522. [4] Nie et al. 2008 ISMRM proceedings, program #3163, or Med Phys. 2008; in press. ***Acknowledgement:*** supported by NIH CA90437, CA121568, CBCRP 9WB-0020 & 14GB-0148.