Development of A Reliable Analysis Method for Measurements of Breast Volume and Fibroglandular Tissue Volume in MRI

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Introduction

Mammographic density is a strong risk factor associated with development of breast cancer. It is referred to the fibroglandular tissue density appeared on mammogram, which can be measured qualitatively or quantitatively. Qualitative methods include Wolfe criteria and the ACR BI-RADS category, as well as other more sophisticated methods assigning different scores. Quantitative method uses computer-aided calculation of fibroglandular area on mammograms through interactive thresholding. The reliability has been a major concern in these approaches [1]. Tissue overlapping and lack of the calibration standard may further lead to inaccurate measurements. Compared to the 2D projection mammography, breast MRI acquires a 3D volume of uncompressed breasts, thus not suffer from these problems. However, only a few studies reported breast density measurement using MRI [2-3]. In these studies breast segmentation was done using pre-set criteria for consistency, only for their limited subjects, not aiming to develop a reliable method for any individual. In this study, we developed a computer algorithm-based method, using fuzzy C-mean classification, b-spline curve fitting and dynamic searching, to extract the breast boundary [4-6], then using FCM for fibroglandular tissue segmentation. The measured total breast volume and the total fibroglandular tissue volume were used to calculate the percent density. The reliability was evaluated.

Methods

A full analysis flow chart is shown in Fig.1. A reliable breast segmentation is the first step for accurate volumetric measurements. Fig. 2 demonstrates the step-by-step segmentation procedure and the final segmented breast. The initial estimate of breast boundary was obtained using individual person's body landmarks to exclude unwanted areas, called V-shape cut. In each subject, the level of the aortic arch is first identified on the axial T1 weighted image, then two lines connecting the lamina process of the thoracic spine and the lateral margin of the bilateral pectoris major muscle can be further defined, resulting in a V-shape cut image in Fig.2b. Then the heart was removed. The resulted image was analyzed by the fuzzy C-means (FCM) algorithm to obtain different classifications (e.g. air-darkest, fibroglandular tissue & chest wall muscle-medium intensity, fat-brightest). The FCM was used to remove air, then the b-spline fitting was used to estimate the breast-chestwall boundary. Then the skin was removed by dynamic searching. Finally the breast was analyzed with FCM for uniformity correction and fibroglandular tissue segmentation simultaneously [7]. The intra- and inter-operator reproducibility was performed in 12 selected studies by 3 operators.

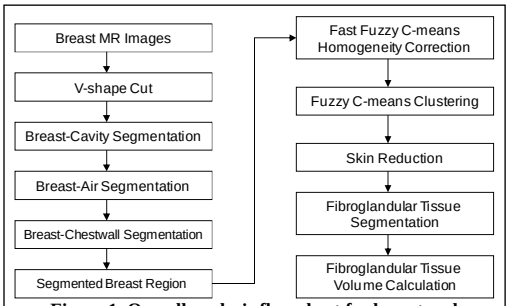

Figure 1. Overall analysis flow chart for breast and fibroglandular tissue segmentation.

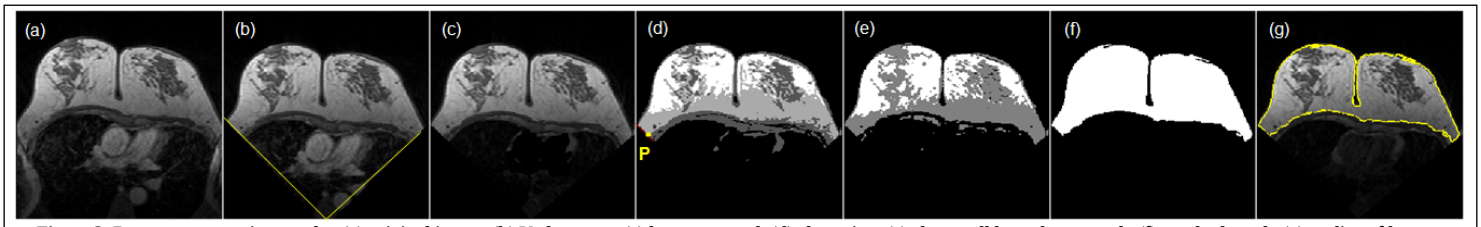

Figure 2. Breast segmentation results, (a) original image, (b) V-shape cut, (c) heart removal, (d) clustering, (e) chest wall boundary search, (f) resulted mask, (g) outline of breast.

Results

An example of fibroglandular tissue segmentation result is shown in Fig 3: a) background uniformity correction using fast fuzzy c-means, b) fuzzy c-means algorithm to classify the fatty and fibroglandular tissue in breast, c) dynamic searching for skin exclusion and separation of left and right sides using the mid-sternum, d) fibroglandular tissue segmentation result. The fuzzy c-means algorithm was applied to perform three tasks, breast segmentation, and the background homogeneity correction along with the fibroglandular tissue classification simultaneously, which saved computational time. We also developed a convenient user interface to allow user interactively adjusting the segmentation and tissue classification by changing the total cluster numbers. The whole process only required 10 minutes on a personal computer with a 3- GHz Intel Pentium 4 CPU with 1 GB RAM processor. However, some manual correction was still necessary. The problem occurred when the image contrast was low, such as at the far superior or inferior slices with coil artifacts, or where the contrast between breast and chest wall muscle was not clear. The mean breast volume and percent fibroglandular density analyzed by 3 operators are listed in Table 1. The intra-operator test-retest correlation and the inter-operator correlation are also summaries in Table 1.

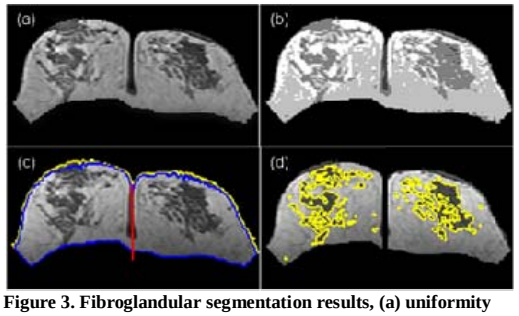

Figure 3. Fibroglandular segmentation results, (a) uniformity corrected image, (b) FCM classification, (c) dynamic searching for skin removal, (d) segmented fibroglandular tissue.

Table 1: The intra- and inter-operator reliability

	Total Breast Volume (cm^3)	Fibroglandular Percentage
Ope#1, trial-1	562.9	13.7%
Ope#1, trial-2	571.8	14.3%
Ope#1, trial-3	564.5	14.2%
Ope#2, trial-1	548.3	13.9%
Ope#3, trial-1	563.0	14.4%
Ope#1 1 vs. 2	0.98	0.98
Ope#1 1 vs. 3	0.99	0.99
Ope#1 2 vs. 3	0.97	0.98
Ope#1 vs. #2	0.97	0.97
Ope#1 vs. #3	0.99	0.99

Discussion

Previous studies have shown that fibroglandular density can be modulated with hormonal interventions. For example, hormone replacement therapy (HRT) increases the density, while tamoxifen decreases the density, suggesting that fibroglandular density may serve as a surrogate marker for evaluating change of density, thus risks. Current evaluation of breast density based on mammogram may suffer from many technical problems such as overlapping tissues (thus, varying with the degree of compression) and lack of a calibration standard, which makes already questionable operator reliability problem worse. This may limit the application of this method for evaluating change of density over time. In this study we developed a method using computer-assisted segmentation for the breast and the fibroglandular tissue to calculate the percent fibroglandular density on breast MRI. The results showed that both intra-operator test-retest reproducibility and the inter-operator consistency were very high. As such, the method may be sensitive to measure small changes reliably. It may also provide an individualized monitoring method for a woman to evaluate her benefits or risks when considering chemoprevention or HRT.

References: [1] Stanten et al. Endocr. Relat. Cancer 2007;14:169-187. [2] Wei et al. Med. Phys. 2004;31:923-942. [3] van Engeland et al. ITMI. 2006;25:273-82. [4] Hayton et al. Med Image Anal. 1997;1:207-24. [5] Arbach et al. ISBI 2004;254-256. [6] Yao et al. SPIE 2005;5747:1942-46. [7] Chen et al. ISBI 2004;1307-1310.

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