Correction of Skin Volume in the Breast Density Measured by MRI

K. Nie[1], D. Chang[1], J-H. Chen[1,2], T-C. Shih[1,2], C-C. Hsu[2], O. Nalcioglu[1], and M-Y. L. Su[1]
[1]Tu & Yuen Center for Functional Onco-Imaging, University of California, Irvine, Irvine, CA, United States, [2]Department of Radiology, China Medical University, Taichung, Taiwan

Introduction:

Most of the current knowledge about breast density was obtained using mammography. The dense tissues (stroma and epithelium) attenuate x-rays more than fat and appear light on mammogram while fat appears dark, and the area of dense tissue normalized to the entire breast area was calculated as "mammographic density". The reliability in measurement of mammographic density, qualitative vs. quantitative, or area-based vs. volumetric measurements, is a current area of research interest. MRI provides 3D images, and a good contrast between fatty and fibroglandular tissues can be generated by most breast imaging pulse sequences. One problem specific to the MRI-based analysis is the inclusion of skin as the dense tissue, because they exhibit similar signal intensities in all sequences, as shown in **Fig.1**. On mammography, the x-ray beam is equally attenuated by two layers of skin everywhere within the field of view of the breast, thus the skin effect can be ignored in the measurement of mammographic breast density. We have developed a method to segment skin, presented in the meeting last year [ISMRM 2009, page 4129]. The purpose of this work is to establish the relationship between skin volume and the breast volume, and compare two different skin correction methods, 1) based on estimated skin volume from breast volume, and 2) based on a fixed percentage.

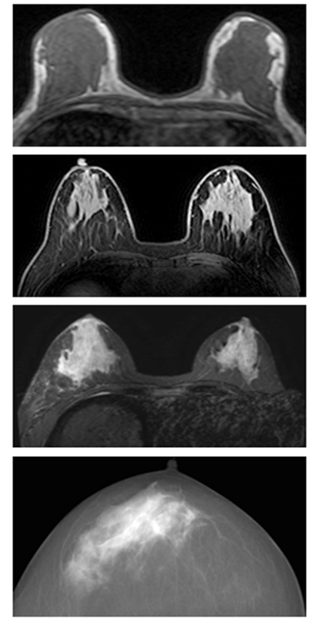

Fig 1. MRI acquired using three different sequences that show different skin contrast. The bottom image shows a mammogram without skin contrast.

Methods:

50 subjects with a broad spectrum of breast densities enrolled from Mar. 2005 to June 2006 were included in this study. MRI was acquired using a Phillips Eclipse 1.5T scanner. Only the normal breast was analyzed. The breast and fibroglandular tissue were segmented using our previously published methods based on fuzzy c-means (FCM) algorithm. As clearly shown in **Fig. 1** (the second image), if the skin were not excluded, it would be categorized into the same cluster as fibroglandular tissue. Dynamic searching was implemented along the direction perpendicular to the breast-air boundary, based on the change of gray level gradient. The upper border of the skin was determined when the negative gradient from skin to air was found; and the lower border was determined when the positive gradient from skin to fatty tissue was found. Up to a maximum of 3 pixels between these two borders were defined as skin. We also investigated the correlation between the volume of the skin and the breast, aiming to provide an estimation of the skin volume based on breast volume. Geometrically, the skin can be treated as a shell covering the breast surface, thus it is reasonable to treat the breast as a semi-sphere, and the skin as semi-spherical shell. Therefore, the cubic square root was used to transform the breast volume while the square root was used to transform the skin volume. After transformation, both parameters became normally distributed, and a linear regression model was used to analyze their relationship.

Results:

The percentage of the skin volume normalized to the breast volume ranged from 5.0% to 15.2% (median 8.6%, mean ± STD 8.8 ± 2.6 %) among 50 women. **Fig.2** shows the correlation between the percent breast densities measured with skin (y) and without skin (x). They were highly correlated, y = 1.23 x + 7% ($r = 0.94$, $p < 0.001$), but it can be clearly noted that the density containing skin is over-estimated. The relationship between the skin volume and the breast volume was analyzed based on transformed data (the square root of the skin volume versus the cubic root of breast volume) using the linear regression. The relationship is expressed as $Volume_{skin}^{1/2} = 0.49 \times Volume_{breast}^{1/3} + 3.3$ with $r = 0.87$, $p < 0.001$. When this model was used to estimate the skin volume for correction in the density analysis, it provided a better fit to the measured density with skin exclusion (with adjusted R-square=0.98, and root mean square error= 1.6) compared to the correction done by using a fixed cut-off value of 8% (adjusted R-square=0.83, root mean square error= 4.7).

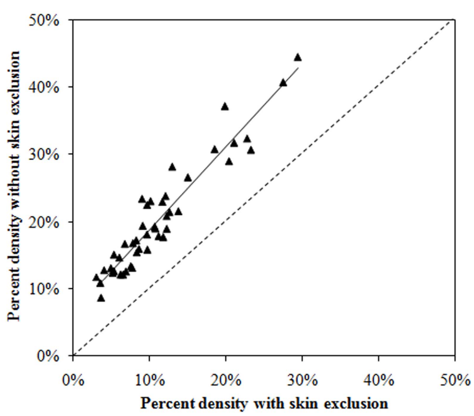

Fig 2. Comparison of the density with and without skin correction. Skin increases density by 5-15%.

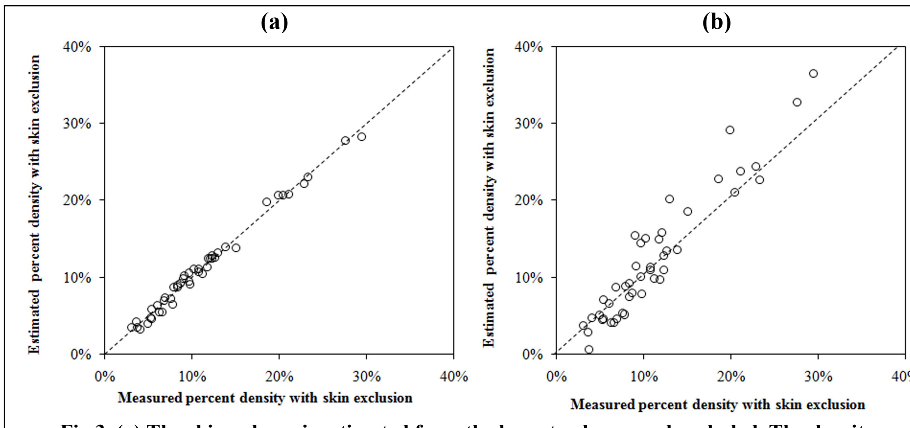

Fig 3. (a) The skin volume is estimated from the breast volume, and excluded. The density measured in this way agrees with the true density well. (b) If a fixed skin effect of 8% is used for correction, the range of density matches, but a substantial deviation from the unity line is noted.

Discussion:

We have shown that the skin volume is related to the breast volume, and this relationship may be used to correct for the skin effect in the MRI-based density measurement. If the skin is not excluded and is misclassified as fibroglandular tissue, this would result a large error in the density measurement. We have provided a model that can be used to estimate the skin volume based on breast volume. There is a great interest to correlate between the density measured on MRI and mammogram, so the established role for mammographic density may be extended to MRI-based density. How the skin is handled may affect these correlation results.

Acknowledgement: This work was supported in part by NIH CA90437 and CBCRP 9WB-0020 and 14GB-0148.