Proceedings of the 26th Annual International Conference of the IEEE EMBS
San Francisco, CA, USA • September 1-5, 2004

Comparison of Fibroglandular Tissue Distributions for Microwave Tomographic Breast Images with Complementary MR T2 Weighted Images

P.M. Meaney[1], C.J. Fox[1], Q. Fang[1], C.Kogel[2], S.P. Poplack[2], B.W. Pogue[1], K.D. Paulsen[1]
[1]Thayer School of Engineering, Dartmouth College, Hanover, NH USA
[2]Dartmouth-Hitchcock Medical Center, Lebanon, NH USA

Abstract—**We have recently demonstrated good correlation between the recovered permittivity from microwave imaging (MIS) and the recovered water content from near infrared imaging (NIR) for a common set of normal patients undergoing associated breast examinations. We have subsequently conducted a small sample of comparison breast examinations between microwave imaging and MR to assess possible correlation between the location and extent of the fibroglandular as seen on MR images with increased permittivity zones of the microwave images. From various physiological and MR breast studies, it has been shown that the fibroglandular regions are generally comprised of significantly higher levels of water than the more dominant adipose tissue. The initial results of this study are quite encouraging and demonstrate obvious correlations between the permittivity and MR-recovered fibroglandular regions for a set of patients with widely varying tissue type variations. In addition, they illustrate the value of extracting diagnostic information from multiple modalities especially where the amount of direct in vivo property measurements is limited or non-existent.**

Keywords—**microwave imaging, breast, fibroglandular, MR, water content**

I. INTRODUCTION

One of the most consistent and consequently intriguing features in our early microwave breast images were localized permittivity increases for women with elevated radiographic densities. These regions appeared primarily in the permittivity images but were often also present in the corresponding conductivity maps. In general, the fibroglandular tissue in the breast has considerably higher water content than the predominant adipose tissue as reported by Woodward and White [1,2] which should correlate to significantly higher permittivity and conductivity according to the work of Foster and Schepps [3]. In an additional study conducted at Dartmouth College, we have compared the average recovered properties from three breast imaging modalities: microwave imaging (MIS), near infrared imaging (NIR), and electrical impedance spectroscopy (EIS), for a common cohort of normal patients versus radiographic breast density and age. A striking cross-modality correlation was observed between the recovered permittivity (MIS) and the recovered water content (NIR). It should be noted that a similar strong correlate was observed in another study between the NIR hemoglobin content and MIS conductivity [4]. Given that elevated hemoglobin content has been shown to be a good predictor of tumor presence [5], it suggests that the conductivity images could be quite useful for tumor detection. This hypothesis is currently being studied. These results in combination with the preliminary observations of localized increased property zones in the recovered permittivity images suggest that the microwave images can recover the fibroglandular regions.

We have initiated a study in a group of women with normal breasts who were imaged both with our microwave system and a standard T2 weighted MR sequence to determine whether the increased permittivity zones observed in the microwave images corresponding to actual features (i.e. fibroglandular tissue) in the breast as determined from the MR scans. The MR system generally produces images with good definition of adipose and fibroglandular structures.

II. METHODOLOGY

The microwave breast imaging exams were conducted using our prototype imaging system at the Dartmouth-Hitchcock Medical Center (Figure 1). The women were prone on the examination table with their breasts pendant in a tank of glycerine and water. The monopole antenna array was mounted on a plate below the tank whose vertical position could be adjusted by a computer-controlled linear actuator. The antennas protruded into the tank thru hydraulic seals in the tank base and surrounded the breast. The microwave electronics were designed such that each antenna could act in both transmit and receive modes allowing data to be acquired for illuminations from all angles in a 2D plane over a wide range of frequencies (generally from 500 – 2500 MHz). Vertical motion of the antenna array facilitated data collection at multiple planes making it possible to reconstruct images over multiple coronal slices of the breast. The microwave examination times were generally under 20 minutes for both breasts. Figure 2 shows a 3D surface rendering of a pair of breasts with various microwave permittivity images transecting the associated planes of the breast. Slight bumps on the surface rendering indicate the location of vitamin E capsules positioned as fiducial markers during the MR examination. Corresponding ink markings were drawn on the breast prior to the microwave examination to facilitate accurate comparison of relevant planes. Fiducial markers positioned at a variety of locations on the breast, including differences in distances from the nipple, were required to help compensate for the differences in breast shape and vertical position identification since the breast is quite buoyant in the glycerine:water bath which causes some degree of compression with respect to the configuration in the MR coil. The microwave data was acquired for the plane closest to the chestwall and at subsequent 1 cm increments.

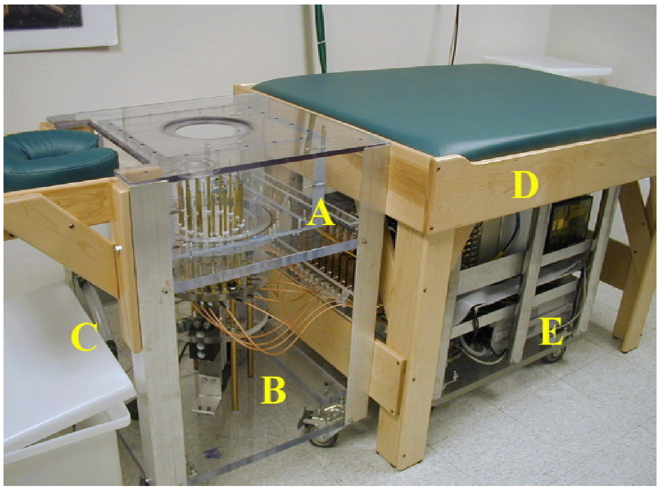

Figure 1. Photograph of the microwave breast imaging system at DHMC: (A) illumination tank, (B) linear actuator, (C) overflow reservoir, (D) patient bed, and (E) electronics cart.

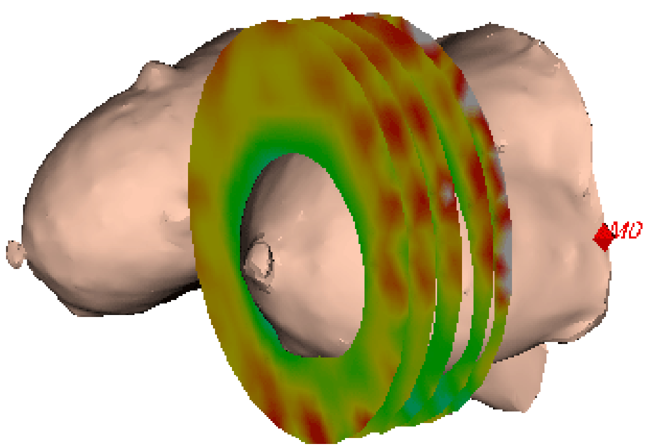

Figure 2. 3D rendering of the breast surface with planar transects to illustrate the geometry of the 2D imaging planes.

III. Results

The images shown in Figure 3 were for seven planes of the left breast of a woman with scattered to fatty radiographic breast density with the first position closest to the chestwall and each subsequent plane spaced by 1 cm increments (spacing was with respect to the microwave image set). The ε_r (relative permittivity) and σ (conductivity) images for each plane are displayed next to the corresponding MR images. The microwave images were for 1100 MHz with an 80:20 glycerine:water background coupling medium (ε_r = 23.5 and σ = 1.14 S/m). The MR images show minimal glandular structure for the planes closest to the chestwall and progressively increasing amounts of fibroglandular tissue in the lower right quadrant as the planes approach the nipple. The permittivity images are relatively homogeneous for the first few slices near the chestwall and exhibit a gradual property increase from plane 4 to plane 7 in the appropriate locations. This is excellent correlation of the larger sections of fibroglandular tissue given the complex distribution. In addition, for the MR images of planes 3 and 4, there appears to be a slight increase of either glandular tissue or vasculature in the central upper area. The permittivity images for both of these positions exhibit a horizontal swath of slightly elevated values which may correspond with this. The conductivity images also exhibit corresponding elevated zones in these same locations suggesting that these increases may be associated with localized vasculature (see discussion below). Other than this, the conductivity images are quite homogeneous and do not appear to detect the glandular zone. The results for the contralateral breast are quite similar (although symmetric) and are not shown.

These results are quite interesting with respect to correlation between permittivity and fibroglandular tissue. In fact, a recent multi-modality comparison (15 patients) showed a correlation coefficient of 0.80 between MIS permittivity and NIR water content (the NIR images were reconstructed for a range of wavelengths from which various constituents such as the water content and hemoglobin content can be extracted on a pixel by pixel basis). These results are especially important in the context that the fibroglandular tissue will generally have higher water content than the corresponding adipose tissue [1,2] and that the water content is the major factor impacting the permittivity at these frequencies [3].

The graph in Figure 4 shows the correlation between the average MIS conductivity and the corresponding NIR hemoglobin content for a set of patients varying in radiographic density and age [4]. In general, elevated hemoglobin content is considered a good predictor of tumor presence [5]. This suggests that the MIS conductivity may also me a good predictor of tumor presence.

IV. Discussion

These preliminary results are quite intriguing with respect to correlations between the microwave and MR images. They also point to the value of utilizing data from other functional imaging modalities such as NIR. With the limited knowledge of in vivo property measurements for the

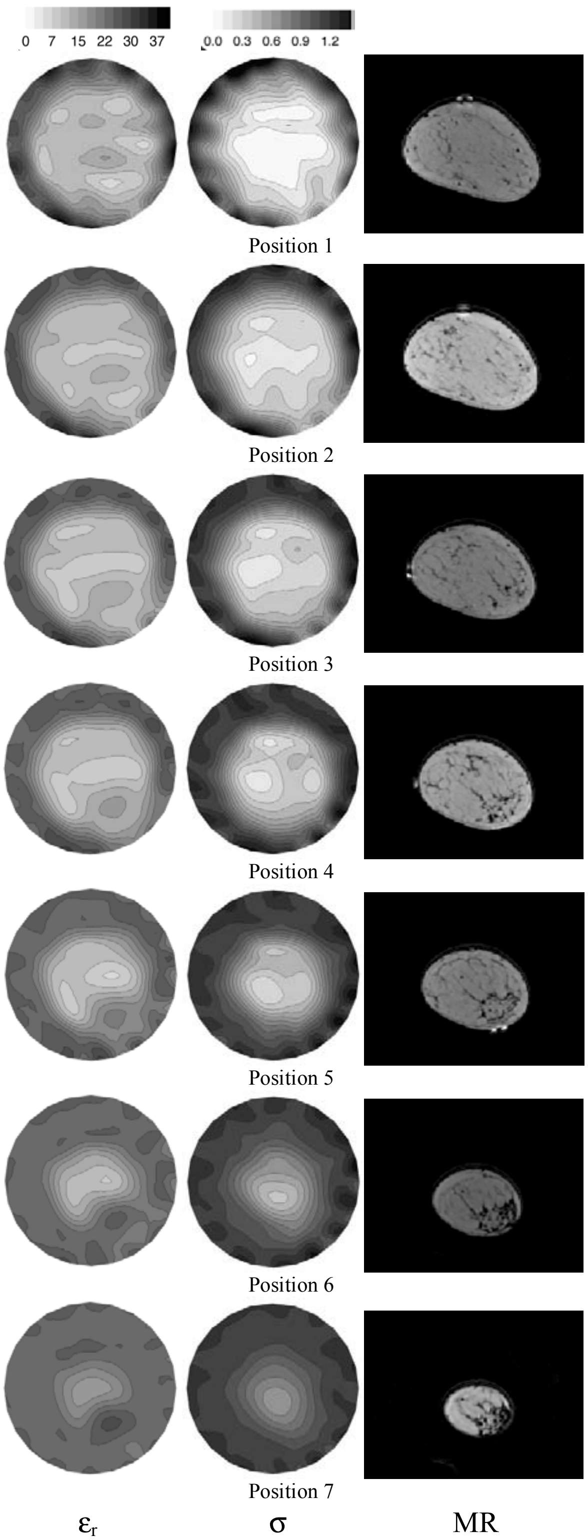

Figure 3. Microwave (left – permittivity and middle column – conductivity) and MR (right column) images for the left breast of a woman with fatty to scattered radiographically dense breasts.

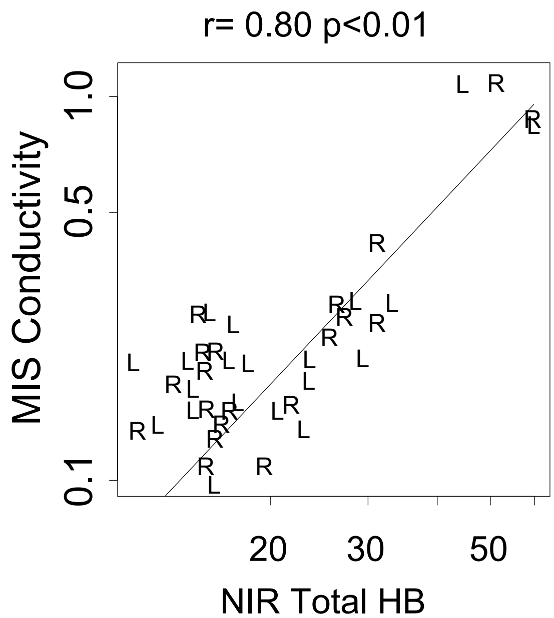

Figure 4. MIS σ vs. NIR Hemoglobin scatter plot

breast and the likely differences between the in vivo and ex vivo [6,7] results, studies like these may prove to be useful alternatives in assessing breast tissue property states in vivo.

ACKNOWLEDGMENT

This work was supported by NIH/NCI Grant # PO1-80139.

REFERENCES

[1] H.Q. Woodward and D.R. White, "The composition of body tissues," *The British Journal of Radiology*, vol. 59, pp. 1209-1219, 1986.

[7] S.J. Graham, et al., "Changes in fibroglandular volume and water content of breast tissue during the menstrual cycle observed by MR imaging at 1.5 T," *J. MRI*, vol. 5, pp. 695-701, 1995.

[3] K.R. Foster, J.L. Schepps, "Dielectric properties of tumor and normal tissues at radio through microwave frequencies," *J. Micro. Power*, vol. 16, pp. 107-119, 1981.

[4] S.P. Poplack, K.D. Paulsen, A. Hartov, P.M. Meaney, B.W. Pogue, T. Tosteson, M. Grove, S. Soho, W. Wells, "Electromagnetic breast imaging – normal tissue property values," *Radiology*, May 2004.

[5] B.W. Pogue, S.P. Poplack, T.O. McBride, W.A. Wells, K.S. Osterman, U.L. Osterberg, K.D. Paulsen, "Quantitative hemoglobin tomography with diffuse near-infrared spectroscopy: Pilot results in the breast," *Radiology*, vol. 218, pp. 261-266, 2001.

[6] S.S. Chaudhary, R.K. Mishra, A. Swarup, and J.M. Thomas, "Dielectric properties of normal and malignant human breast tissues at radiowave and microwave frequencies," *Indian. Journal of Biochemistry and Biophysics,* vol. 21, pp. 76-79, 1984.

[7] W.T. Joines, Y. Zhang, C. Li, and R.L. Jirtle, "The measured electrical properties of normal and malignant human tissues from 50 to 900 MHz," *Medical Physics*, vol. 21, pp. 547-50, 1994.